PROPOSED PLAN TO ADDRESS ZONE D GROUNDWATER F. E. WARREN AIR FORCE BASE, WYOMING

This Proposed Plan identifies the preferred alternatives for treating contaminated Zone D groundwater at F. E. Warren Air Force Base (F. E. Warren). In addition, this Plan provides the rationale for these preferences and includes summaries of the other cleanup alternatives that were evaluated for use at this site. The United States Air Force (USAF), the United States Environmental Protection Agency (EPA) as the lead regulatory agency, and the Wyoming Department of Environmental Quality (WDEQ) as the support agency have collectively issued this document.

A final remedy for Zone D will be selected following review and consideration of all the relevant information presented. The preferred alternatives may be modified or alternative response actions selected depending upon new information or public comments. Therefore, the public is encouraged to review and comment on all the alternatives presented in this Proposed Plan. The public comment period will last from 22 February 2005 to 24 March 2005. A public meeting on these alternatives will be held on 22 February 2005.

The proposed remedial alternatives for high concentration areas within Zone D (i.e., areas in Plumes B, C and E and Spill Site 7 [SS7]) include chemical oxidation or bioaugmentation for the shallow- and intermediate-depth groundwater zones (with the exception of the intermediate zone at Plume C). In addition, permeable reactive barriers (PRBs), another form of in-place treatment, are a component of the groundwater treatment for Plumes C and E, and SS7. Plume A and the lower contaminant concentration areas of the aforementioned plumes are expected to gradually clean themselves up through natural processes using a remedy called Monitored Natural Attenuation (MNA). Lastly, the final Zone D remedy also recommends no further action for soil and groundwater at the former Landfill 2 (LF2) and no further action for groundwater associated with SS2, SS4 and Fire Protection Training Area 2 (FPTA2). LF2 achieved clean closure with excavation and off-site removal of the landfill contents during an earlier response action. Soils at SS2, SS4, and FPTA2 require no further action based on previous response actions, and groundwater investigations at these sites reported no evidence that these sites are contributing to groundwater contamination.

Due to the relatively large sizes of the contaminant plumes and the low permeability of the soil, it will generally take decades to clean most of the plumes, and in some cases longer. All of the proposed remedies include Land Use Controls (LUCs) to limit access and future use of groundwater. The remedies will be reviewed no less than every five years to assure that protection of human health and the environment are maintained.

Descriptions of all the proposed remedial action technologies are provided in this document, along with a summary of the alternatives evaluated, the time frame to achieve clean up goals, and estimated costs for implementing and maintaining each alternative. The summary table at the back of this plan (Table 8) summarizes all of the remedial actions considered for each plume, along with a brief description of the preferred remedial action.

PUBLIC MEETING

22 February 2005
7:00 p.m.

Little America Motel & Resort, Regency Room,
2800 West Lincolnway
Cheyenne, Wyoming

PUBLIC COMMENT PERIOD

22 February 2005 to 24 March 2005

For more information, see the Information Repository at the following location:

Laramie County Library
2800 Central Avenue
Cheyenne, WY 82001-2702
(307) 634-3561
Hours: Mon –Thur
10:00 a.m. - 9:00 p.m.
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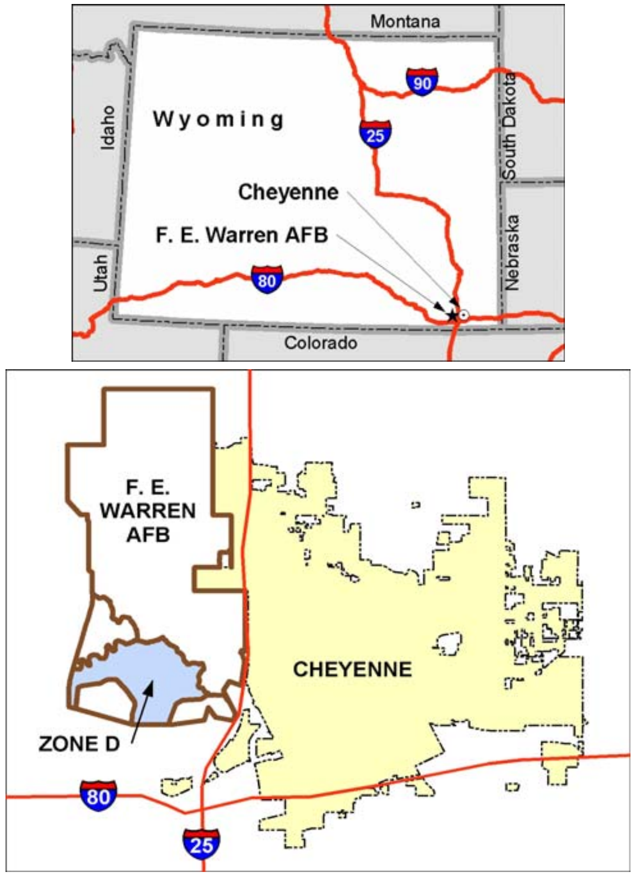


FIGURE 1 - F. E. WARREN AIR FORCE BASE LOCATION MAP

INTRODUCTION

The USAF has prepared this Proposed Plan in accordance with Section 300.430(f)(2) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and as part of its public participation responsibilities under Section 300.430(f)(3).

The Proposed Plan summarizes information contained in the Administrative Record for this zone. Documents in the Administrative Record are also available at the Information Repository for F. E. Warren, which is located at the Laramie County Library in Cheyenne, Wyoming. The USAF, EPA, and WDEQ encourage the public to review these documents to gain a more complete understanding of the zone and Superfund activities. The Zone D Groundwater Remedial Investigation (RI) report assesses the nature, extent, fate, and transport of contamination, along with assessing risk to human health and the environment. The Zone D Groundwater Feasibility Study (FS) identifies and screens a variety of remedial technologies and develops and evaluates proposed alternatives for cleaning up the contaminated groundwater.

Based on information available at this time, the USAF, EPA, and WDEQ believe the preferred alternatives will be protective of human health and the environment and will comply with applicable or relevant and appropriate requirements (ARARs). The preferred alternatives can change in response to public comment or new information.

SITE BACKGROUND

F. E. Warren is located on 5,866 acres adjacent to the western city limits of Cheyenne, which is located in southeast Wyoming (Figure 1). In the late 1980's, F. E. Warren entered into the USAF's Installation Restoration Program (IRP) and environmental investigations were conducted. F. E. Warren was placed on EPA's National Priorities List (NPL) in February 1990. The installation-wide RI identified 20 IRP sites. These IRP sites were first grouped into operable units (OUs) based on site type, location, and projected response action, and subsequently the OUs were grouped into Zones A through E to facilitate and streamline investigation.

Zone D is generally defined as that portion of F. E. Warren east of Roundtop Road along the western boundary of the base, south and west of Crow Creek, south of Diamond Creek, and excluding Zones B and C (see Figure 2). Current Zone D land uses include residential housing, industrial, aircraft operations and maintenance, community (commercial and services), administrative offices, and open space. The F. E. Warren General Plan describes future land uses that will include areas for outdoor recreation in addition to the current land uses.

Zone D contains three SSs (SS2, SS4, and SS7); two LFs (LF2 and LF7); one acid dry well (ADW) area; and two FPTAs (FPTA1 and FPTA2) (Figure 2). Under direction of the USAF, and with concurrence from EPA and WDEQ, the RI for Zone D was divided into two components – the Source Areas RI (OU13), which addressed contaminant sources in the unsaturated zone (i.e., above the groundwater table) and the Groundwater RI (OU2 and OU9 [LF2]), which addressed contaminants in the saturated zone groundwater. This Proposed Plan addresses the groundwater component of Zone D.

Groundwater contaminants within Zone D include trichloroethene (TCE), an organic solvent, and its breakdown products dichloroethene (DCE) and vinyl chloride. TCE has been identified as a widespread contaminant in Zone D groundwater; DCE and vinyl chloride are less widespread and occur at lower concentrations. The contaminants occur in five principal groundwater plumes, Plumes A, B, C and E, and SS7. What historically was referred to as Plume D in OU2 groundwater was determined not to exist during the Zone D RI. Surface water was also investigated as part of the RI to assess the impact from groundwater discharge at Plume A, SS7, and Plume C.

PREVIOUS ACTIONS IN ZONE D

A base-wide RI conducted in 1991 represents the first comprehensive investigation at F. E. Warren. RIs were conducted at OU1, OU4, OU5, OU9, and OU10 between 1992 and 1995. During these RIs, groundwater from many monitoring wells located within Zone D were sampled and analyzed for potential contaminants of concern.

Response actions have been implemented at several sites within Zone D to mitigate risks to human health and the environment. Interim efforts in Zone D include excavation of waste material at LF2, excavation of impacted soil at SS4 and the ADW, bioventing at FPTA1, removal of a grease trap and impacted soil at SS7, groundwater extraction and air stripping at SS7, installation of a zero-valent iron (ZVI) permeable reactive barrier (PRB) for groundwater at SS7, and the recent removal, treatment and replacement of additional SS7 soil using soil vapor extraction (SVE).

Groundwater associated with OU10 (FTPA1 and LF7) is being addressed under a separate action associated with the Zone D Source Areas RI/FS.

ZONE D RECORDS OF DECISION

There have been five previously completed Records of Decisions (RODs) for IRP sites within Zone D; four final and one interim. The OU4 ROD (1992) addressed soil and groundwater contamination associated with the ADW at an old transportation complex. Based on previously completed contaminated soil removal, the Baseline Risk Assessment (BRA) indicated no significant risk to human health and the environment. Therefore, no further action for soil or groundwater was required at this site.

The ROD for OU5 addressing the FPTA2 soils (1996) indicated no further action was required based on the risk assessment findings of no significant risk to human health and the environment. As part of this decision, groundwater beneath FPTA2 was made part of OU2.

The OU1 ROD (1996) addressed contaminated soils at SS1 through SS7. Closure decisions were based on low contaminant concentrations, findings of insignificant risk to human health and the environment, and/or adequacy of implemented IRAs in addressing excessive soil contamination. As indicated in the closure documents, the No Further Action decisions do not consider potential impacts to groundwater related to leaching and migration of residual contaminants in soil. In the case of SS7, the closure was based on surface contact risks. Subsequent data from SS7 indicate that additional subsurface action is required. Groundwater beneath SS1 through SS7 was not included in the RODs, and therefore it was made part of OU2.

A ROD for LF7/FPTA1, part of OU10, was signed in 2004. The recommended action is groundwater monitoring to determine background concentrations and document that the landfills are not contributing to groundwater contamination.

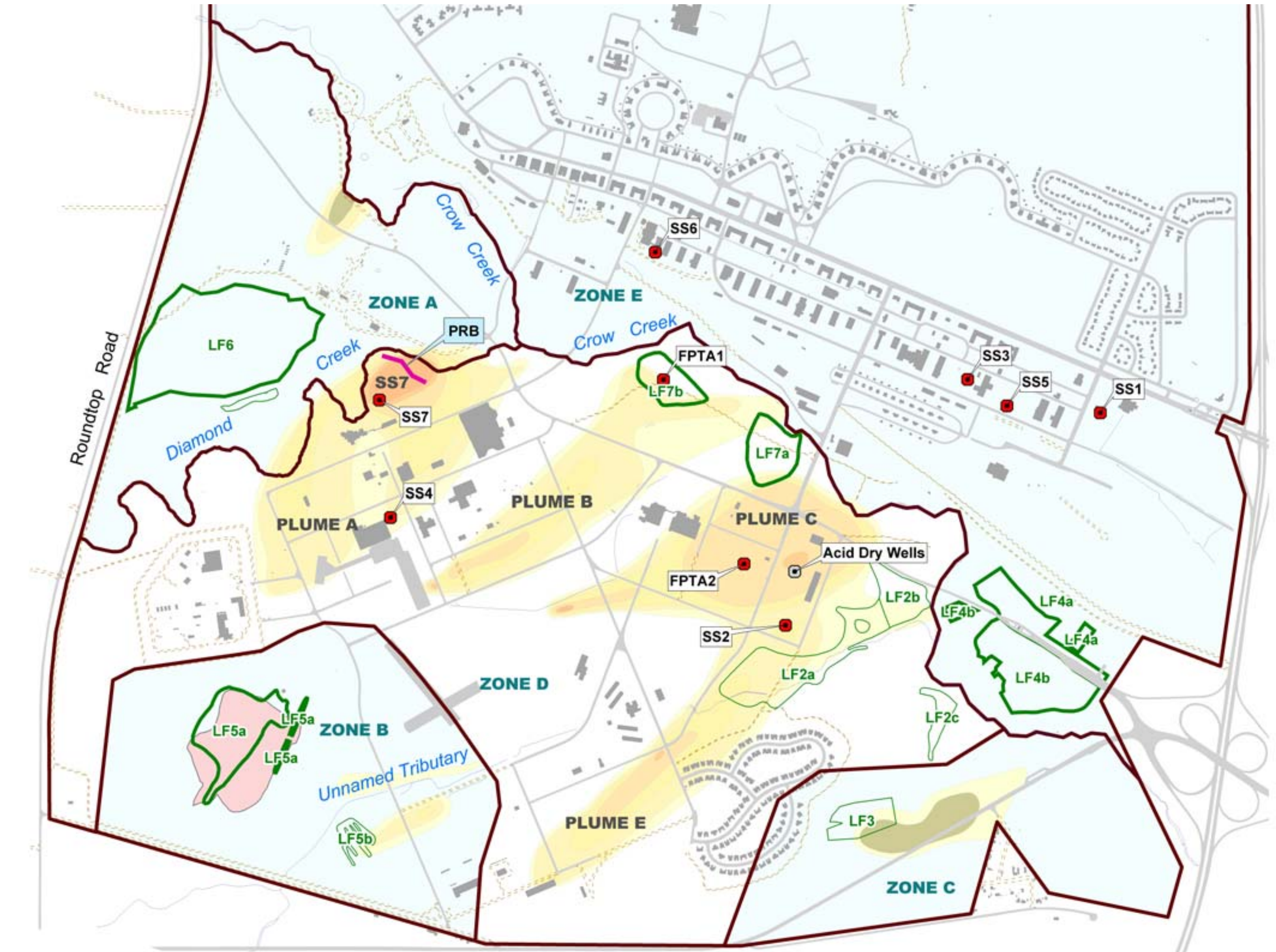


FIGURE 2 - ZONE D AND SURROUNDING AREA

An interim ROD for an IRA for treatment of shallow groundwater at SS7 (part of OU2) using an iron filings wall was signed in 1997. The IRA's purpose was to reduce contaminant concentrations in shallow groundwater and minimize contaminant loading to Diamond Creek. Monitoring of the iron filings PRB is being performed under the installation-wide long-term monitoring (LTM) program.

ONGOING INVESTIGATIONS

Ongoing investigation activities that are related to portions of Zone D groundwater include treatability studies, LTM programs, and the Zone D Source Areas RI.

Multiple treatability studies have been conducted in association with Zone D groundwater. These treatability studies have served two primary purposes: (1) to aid in the selection of a final remedy for Zone D groundwater, and (2) to aid in implementation of the selected remedy by providing site-specific details. The studies were performed in accordance with EPA's Guidance for Conducting Treatability Studies Under CERCLA.

The installation-wide LTM program has been active since 2000. The LTM program in Zone D includes performance monitoring of the SS7 PRB. Data collected for the SS7 PRB includes groundwater and surface water elevation data, surface water flow discharge measurements, and contaminant concentrations in groundwater and surface water. These data are collected to monitor the transport (movement) and attenuation (reduction) of the SS7 plume. These data have been evaluated as part of the Zone D Groundwater RI and provide additional insight into groundwater and surface water interaction and contaminant distribution.

An LTM program will be developed for the full extent of the treatment period (MNA and active remedies) within each plume until RAOs are achieved. The LTM program will be reviewed and modified accordingly, as new data are obtained during the monitoring period. Performance monitoring will apply to the shallow and intermediate groundwater zones of Zone D, in addition to existing surface water stations. LTM would allow for continued evaluation of contaminant migration and effectiveness of the remedial actions implemented, in addition to ensuring the remedy is protective of human health and the environment.

The Zone D Source Areas RI is closely linked to the Zone D Groundwater RI. The Source Areas RI focused on contaminant sources within the vadose (unsaturated) zone, although some groundwater investigation was necessary to help delineate the vadose zone sources. The Groundwater RI addressed contamination within the saturated zone. As such, the Groundwater RI incorporated some of the groundwater data collected during the Source Areas RI for an improved understanding of the nature and extent of contamination in groundwater. For details regarding vadose sources associated with the Zone D groundwater plumes (Plumes A through E and SS7), refer to the Zone D Source Areas RI.

SITE CHARACTERISTICS

The site characteristics described below apply collectively to all the plumes within Zone D. In subsequent sections, site characteristics that are unique to the respective plumes are discussed within the context of each plume.

HYDROLOGY

Crow Creek is the major perennial (permanent) stream that drains to the southern areas of F. E. Warren and defines the northern and eastern boundary of Zone D (Figure 2). Crow Creek originates in the Laramie Mountains west of Cheyenne and flows southeastward to the South Platte River. Small tributaries (branches) to Crow Creek that also drain parts of F. E. Warren are Dry Creek, North Fork Dry Creek, Diamond Creek, and three unnamed creeks. Diamond Creek, the second largest stream entering F. E. Warren, defines the northern boundary of Zone D where it enters the installation and joins Crow Creek within the Zone D study area (Figure 2).

According to Chapter 1 of the Wyoming Water Quality Rules and Regulations (WWQRR), Crow Creek is classified as a 2AB stream that supports game fish and drinking water, and has a TCE standard of 2.7 µg/L. According to WWQRR, Diamond Creek is classified as a 3B stream that supports aquatic organisms other than fish. Class 3B streams have no applicable TCE standards.

The Unnamed Tributary of Crow Creek has alternating reaches that are perennial, intermittent (irregular), and ephemeral (temporary). The Unnamed Tributary begins near the southwest corner of F. E. Warren, flows northeast, and enters Crow Creek downstream of Missile Drive (Figure 2).

Groundwater seeps occur where the groundwater surface intersects the ground surface. These seeps are evident along terraces of the floodplain and are identified by growths of aquatic vegetation or seasonal pooling of water.

GEOLOGY

The uppermost geologic unit in the F. E. Warren area consists of Quaternary-age terrace and alluvial (water-deposited sediments) deposits composed of clay, silt, sand, gravel, and occasional boulders. The thickness of these deposits varies, but is generally less than 25 feet in depth. The Tertiary-age Ogallala Formation, with an estimated thickness of approximately 300 feet, lies beneath the Quaternary deposits. The sedimentary units composing the Ogallala Formation are understood to have been deposited under fluvial (stream and river) and localized eolian (windblown) conditions in a humid, alluvial fan environment.

SOILS

Several soil types are present at F. E. Warren. However, where average topsoil depths range from 4 to 6 inches, the principal soil series is classified texturally as loamy (loose-textured clayey sand). The subsoil extends from a depth of approximately 6 to 36 inches and is primarily alluvial clay.

HYDROGEOLOGY

Depth to the water table in Zone D is typically 10 to 30 feet below ground surface (bgs), with progressively shallower groundwater depths occurring near Crow and Diamond creeks. However, there are some topographically higher areas where the depth to the water table is greater than 40 feet.

In general, shallow groundwater flow mimics the surface water flow patterns defined by Crow Creek and Diamond Creek. Groundwater flow directions are generally toward the creeks with regional groundwater flow to the southeast in the downstream direction of Crow Creek.

The horizontal hydraulic gradients (change in water table elevation per unit horizontal distance) in shallow groundwater range from approximately 0.006 to 0.03 foot/foot and tend to be steepest near the creeks. The typical hydraulic gradient is approximately 0.01 foot/foot.

In areas away from Crow Creek and Diamond Creek, downward hydraulic gradients (downward flow of water in the ground) have been observed. Upward hydraulic gradients (upward flow of water in the ground) are generally evident in well clusters located near the creeks, providing evidence that groundwater discharges to the creeks. Some well clusters in Zone D exhibit a mixture of gradients. Artesian conditions have also been observed in some wells.

Recharge to the shallow aquifer occurs by local precipitation (rainfall and snow) and flow from upgradient sources. In addition, there may be areas within the creek floodplains where upward vertical gradients do not exist, and surface water may recharge shallow groundwater.

Water levels in wells have been shown to have seasonal fluctuations; rising as much as 5 feet following periods of high precipitation and falling during drier periods. The greatest fluctuation in groundwater elevation at any of the Zone D wells during the period of record (up to 12 years) is approximately 8 feet. Typically, spring is the wettest time of year, and water levels rise in late spring and early summer.

The measured hydraulic conductivity values for the shallow wells range from 0.03 to 107.7 feet/day and 0.01 to 29.56 feet/day for the intermediate wells. The horizontal groundwater velocity is approximately 0.15 feet/day (54 feet/year) in both shallow and intermediate zones. Due to the highly variable nature of site geologic conditions, site groundwater velocities are expected to vary considerably.

The aquifer system at F. E. Warren is distributed into three broad zones: shallow, intermediate, and deep. These zones are based upon differences in aquifer properties and hydrologic conditions documented within the system of monitoring wells installed throughout the site. The shallow zone is composed of Quaternary-age terrace and alluvial deposits. The intermediate zone is composed of Tertiary-age Ogallala Formation, consisting of a heterogeneous mixture of clay, silt, poorly sorted sand, and gravel layers. In general, hydrologic conditions vary with depth such that in the shallow zone the aquifer is more permeable and water flows more freely, and in the intermediate and deep zones, the aquifer is less permeable. The thicknesses of these zones are approximately 20, 30, and 40 feet, respectively, with the base of the deep aquifer zone residing at approximately 90 feet below the water table.

NATURE AND EXTENT OF CONTAMINATION

Groundwater

TCE has been identified as a widespread contaminant in Zone D groundwater and was reported during the RI at a maximum concentration of 13,170 micrograms per liter (μg/L) at SS7. The federal maximum contaminant level (MCL) for TCE is 5 μg/L. This contaminant is distributed in the five groundwater plumes identified as Plumes A, B, C, and E, and SS7 (see Figure 3).

The plumes vary in length, ranging from 600 feet (SS7) to 5,000 feet (Plume E). Plume widths range from approximately 800 to 1,000 feet. The vertical extent of contamination in groundwater generally does not extend deeper than 60 to 80 feet below the ground surface and appears to be limited to the shallow and intermediate aquifer zones.

The source areas of the plumes were investigated as part of the Source Areas RI. Due to the age of the plumes and the associated natural attenuation, there were no discrete source areas identified for Plumes A, B, C, or E. A source area was identified at SS7 and an action to remove and treat the source was undertaken.

The total estimated mass of TCE within Zone D groundwater is 1051 pounds (lbs.). The following table summarizes Zone D plume characteristics including estimated plume acreage, contaminant depths, contaminated groundwater volumes, and TCE concentration/masses within each plume. The vertical distribution of each TCE plume (in acres) was delineated using TCE results from well clusters specified in the FS in which TCE concentrations exceeded the federal MCL of 5 μg/L.

Table 1 – ZONE D PLUME CHARACTERISTICS

Zone within Plume	Estimated Acreage	Max. Identified Depth of Contamination (bgs)	Approximate Volume of Plume (x 10^7 gallons)	Mass Distribution		Maximum TCE Concentrations (µg/L)
				(kg)	(lbs)	
Plume A (excluding SS7)						
Shallow	79	99	10.29	44	97	102.2
Intermediate	10		1.96			
Total	--		12.25			
SS7						
Shallow	30	29	3.91	216	475	13,170
Intermediate	7		1.37			
Total	--		5.28			
Plume B						
Shallow	78	68	10.17	30	66	102.7
Intermediate	12		2.35			
Total	--		12.52			
Plume C						
Shallow	81	52	10.56	130	286	6,870
Intermediate	37		7.23			
Total	--		17.79			
Plume E						
Shallow	92	85	11.99	57	125	449.7
Intermediate	28		5.47			
Total	--		17.46			

Notes:
bgs =feet below ground surface
Data provided in this table can be referenced in the RI/FS.

Surface Water

Surface water sampling was conducted to assess the impact on surface water from groundwater discharge at Plume A, SS7, and Plume C. Data from the LTM Program were also evaluated to develop a comprehensive understanding of the groundwater-surface water interaction. In general, contaminant levels in surface water appear to vary according to stream flow and base flow. Higher concentrations of contaminants in surface water appear to occur during lower stage levels when baseflow is proportionally the greatest.

Based on data collected during the RI, Wyoming surface water standards for TCE (2.7 µg/L) were exceeded in Crow Creek only at station C5.2 (12 µg/L). This station is located at the intercept of Plume C (Figure 3). Plumes B and E have not contributed to any documented exceedances of the TCE standard in Crow Creek. In addition, decreasing concentration trends in these plumes are presumed to preclude any future exceedances at corresponding surface water locations. SS7 has indirectly contributed to exceedances in Crow Creek as described in the subsequent paragraphs.

LTM data indicate that TCE has been detected in Diamond Creek at a maximum concentration of 33 µg/L in January 1989 at station D4. During the June 2004 LTM activities, TCE was detected at concentrations of 4.2 µg/l and 1.9 µg/l in samples collected from stations D3.6 and D4, respectively. There are no TCE standards for Diamond Creek, a Class 3B stream. However, Diamond Creek flows into Crow Creek and accordingly requires surface water treatment at SS7. Historical TCE data for the first Crow Creek surface water station downstream of the confluence with Diamond Creek (C3.5) were found to exceed the Wyoming standard. These TCE results were compared to results from station D4 in Diamond Creek and a correlation in TCE concentrations between these locations was observed. Therefore, TCE concentrations in Crow Creek may occasionally exceed the Class 2AB standards (2.7 µg/l for TCE) due to the influx (entry) of TCE-contaminated water from Diamond Creek.

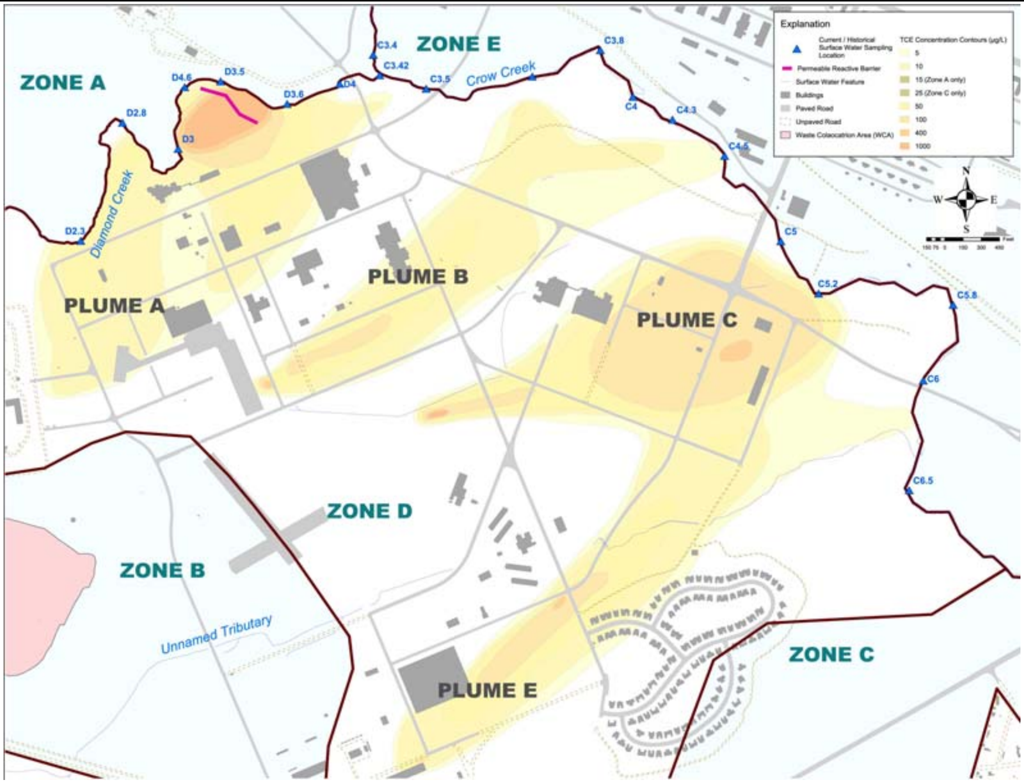


FIGURE 3 - ZONE D PLUMES AND SURFACE WATER SAMPLING STATIONS

SUMMARY OF SITE RISKS

A human health risk assessment was conducted to determine if groundwater in Zone D poses an unacceptable risk to human health. Analytical results for groundwater in Plumes A, B, C, and E and indoor air in residences in Carlin Heights (Figure 3) were used to identify contaminants of potential concern (COPCs) for evaluation in the risk assessment. The primary contaminant of concern (COC) identified is TCE. Other COCs include breakdown products of TCE and include *cis*-1,2-DCE, *trans*-1,2-DCE and vinyl chloride.

A site contaminant is a chemical present at elevated concentrations in a medium because of a release that is attributable to site activities. A **contaminant of potential concern (COPC)** is a contaminant selected for further evaluation in a human health or ecological risk assessment because it may threaten human health or the environment. COPCs are first identified as potential site contaminants – a chemical present at elevated concentrations attributable to site activities. A COPC becomes a **contaminant of concern (COC)** when the chemical occurs at a concentration that poses an unacceptable threat to human health and the environment.

Groundwater beneath F. E. Warren has not been formally classified by the WDEQ for a specific use. There is no current or planned human use of groundwater from Zone D. Additionally, the reported TCE plumes in groundwater do not flow off base; and model simulations of future conditions do not indicate that these plumes will ever move off base.

The City of Cheyenne, Wyoming, Board of Public Utilities (BOPU) supplies and satisfies all requirements for water at F. E. Warren and will continue to meet F. E. Warren's future water needs. It is improbable that humans will use Zone D groundwater in the foreseeable future; and therefore, pathways related to domestic use of groundwater were not evaluated in the risk assessment. Shallow groundwater in areas surrounding the base is used for drinking and agriculture.

Based on current and future land use scenarios, potential receptors identified for groundwater in Zone D were current/future on-site residents living in Carlin Heights and dormitories, current/future on-site commercial/industrial workers, current/future on-site utility/construction workers, current/future on-site recreational visitors, future on-site residents living outside of Carlin Heights and existing dormitories, and future on-site commercial/industrial workers in buildings in currently undeveloped areas in Zone D.

Risk was calculated for exposure to indoor air by current/future residents in Carlin Heights located over Plume E; future residents located over Plumes A, B, C, and E; and current/future commercial/ industrial workers in buildings located over Plumes A, B, C, and E. Risk was not calculated for exposure to indoor air at SS7 because (1) buildings will not be built at SS7, which is located adjacent to the floodplain of Diamond Creek, and (2) the concentrations of volatile organic compounds (VOCs) in groundwater would clearly pose an unacceptable risk to hypothetical receptors breathing indoor air at SS7. (VOCs are a class of chemicals which include TCE and its degradation products DCE and vinyl chloride).

During the course of the RI, potential risk was identified for residents of Carlin Heights that live in homes overlying Plume E. The concern is that TCE in groundwater has the potential to volatilize to soil gas, which could then migrate toward the surface, potentially accumulate in the indoor air of houses, and cause health risks to the residents. To confirm results of the modeling, indoor air samples were collected from living and crawl spaces in the houses overlying the plume, and a number of homes that were considered background or reference locations. Atypical results in one of the background homes led to soil gas and outdoor air surveys. Results of the soil gas and outdoor air surveys suggested that the sources of the atypical results in the background home were likely due to VOCs in outdoor air and from indoor sources (e.g., household products). Information regarding indoor air in Zone D is summarized in the RI Report.

Based on the human health risk assessment, it can be concluded with reasonable certainty that:

- Volatilization of TCE from groundwater to indoor air does not pose an unacceptable cancer risk to current/future residents or commercial/industrial workers in Plumes A, B, E, and most of Plume C. Currently there are no residents living above Plumes A, B and C.
- Volatilization of TCE from groundwater to indoor air could pose a cancer risk higher than $1X10^{-04}$ to $1X10^{-06}$ (EPA cancer risk range for CERCLA sites) to future residents or future commercial/industrial workers in buildings located in Plume C over the maximum measured TCE concentration in groundwater (450 µg/L).
- VOCs in groundwater associated with SS7 would pose an unacceptable risk to future residents or commercial/industrial workers breathing indoor air if buildings were present at SS7.

CONTAMINANT OF CONCERN – Trichloroethene (TCE)

The main contaminant in groundwater at Zone D is TCE, a volatile organic compound (VOC). VOCs are not found naturally in the environment and are usually manufactured as fuels, solvents or degreasers. They can also occur as breakdown products of other VOCs. TCE was detected as a result of the USAF IRP investigations of groundwater contaminants conducted in the late 1980s. The source of this TCE and its degradation products (cis-1,2-DCE, trans-1,2-DCE, vinyl chloride) was disposal or leakage of solvents from either maintenance facilities or unknown sources throughout the southern portion of F. E. Warren.

The base-wide *Surface Water Risk Assessment,* in conjunction with a risk evaluation of surface water data from the Zone D Groundwater RI and the base-wide LTM program, indicate:

- Sediments, surface water, and fish in Crow Creek and Diamond Creek in Zone D do not pose an unacceptable threat to human health.
- No site-related ecological risk was identified for aquatic receptors.

The conclusions from groundwater modeling are:

- Groundwater discharge to creeks and evapotranspiration (loss of water into the atmosphere directly from soil and through plants) by deep-rooted plants that get water from a permanent ground supply or from the water table play important roles in stopping the TCE plumes within the floodplains. During the last decade, the simulated rate of mass loading to Crow Creek and Diamond Creek is 100 kg, and the rate of mass extracted by evapotranspiration is 80 kg.
- The model estimate for remaining TCE mass in the aquifer is 553 kg, which includes both dissolved phase (in water) and sorbed phase (attached to soil). This is based on a typical soil-water distribution coefficient of 0.252 cubic centimeters per gram (cm^3/g) and a typical effective porosity of 0.2.

- Temporal decreases in measured TCE concentrations site-wide, except at SS7 and a portion of Plume C, indicate that biodegradation (breakdown of materials into simple components by microbes) is occurring.

It is the USAF's, EPA's, and WDEQ's current judgment that the preferred alternatives identified in this Proposed Plan, or one of the other measures considered in the Proposed Plan, is necessary to protect public health or welfare or the environment from actual or threatened releases of hazardous substances into the environment.

REMEDIAL ACTION OBJECTIVES

RAOs are site-specific initial cleanup objectives that have been established based on the nature and extent of contamination, potential for human and environmental exposure, and ARARs. The RAOs provide the basis for selecting appropriate response actions, remedial technologies, and for developing alternatives.

The following RAOs have been identified:

- Restore groundwater to beneficial use, where restoration means TCE and its degradation products (DCE and vinyl chloride) meet their respective maximum contaminant levels (MCLs from Wyoming Groundwater Quality Standards).

- Prevent concentrations of TCE and its degradation products in surface water from exceeding the class-specific surface water standards listed in Chapter 1 of the WWQRR.

The surface water RAO applies directly to Crow Creek, which is designated as a Class 2AB stream under the WWQRR, and has a TCE standard of 2.7 μg/L. Diamond Creek, a Class 3B stream, does not have applicable TCE standards; however, the contribution of TCE from SS7 to Diamond Creek presents a potential impact to Crow Creek because Diamond Creek flows into Crow Creek. Contribution of TCE to the surface waters of Diamond Creek has been addressed within the remedial alternatives for SS7.

SUMMARY OF REMEDIAL ALTERNATIVES

Remedial alternatives for Zone D groundwater are presented for each plume. The alternatives correspond with the alternatives presented in the FS. The costs and time to achieve RAOs for each alternative are included. General response actions and process actions describe technologies that will satisfy the RAOs. Alternatives that have been previously described are not included in subsequent plume discussions, as the technology description can be referenced previously in the document.

A wide range of acceptable groundwater treatment technologies and surface water discharge technologies were identified in the FS. Three-dimensional groundwater models were run to select the best combinations of these technologies for developing alternatives and defining their optimum implementation locations. In some instances, treatment of localized areas in relatively higher TCE concentration areas of the plume was nearly as effective as treating the entire plume. This is due to the ongoing natural attenuation in the relatively lower concentration areas of the plume. Therefore, some alternatives were optimized by taking into account the best balance of localized treatment, time for cleanup, and cost. Modeling results are presented in Volume 2 of the FS.

Alternatives for each plume were developed, analyzed, and compared in the FS. LUCs were incorporated into all alternatives, except for the No Action Alternative, although the alternative names do not implicitly state that they are included.

Costs presented for each alternative include capital, total and average annual operations and maintenance (O&M), and present value. Capital costs are the expenditures needed to bring technologies associated with an alternative to an operable status. O&M costs are expenditures associated with the continued operation and maintenance required to implement technologies and administrative activities associated with an alternative. Present value costs are the total capital costs (including markups) and total O&M costs (including markups) defined in "today's dollars" or present value of the total expenditures for an alternative.

FOLLOWING IS A PLUME-BY-PLUME DESCRIPTION WHICH INCLUDES: NATURE AND EXTENT, SUMMARY OF REMEDIAL ALTERNATIVES, EVALUATION OF ALTERNATIVES, AND SUMMARY OF THE PREFERRED ALTERNATIVE FOR EACH PLUME

PLUME A

PLUME A NATURE AND EXTENT

In Plume A, TCE distribution indicates three overlapping sub-plumes. Two of these plumes appear to originate from attenuating sources – one near the WSA and one in the vicinity of SS4. The third plume originates from a continuing source at SS7. Maximum reported TCE concentrations in the other two plumes are 102.2 and 43.62 µg/L, respectively. Reported TCE concentration data and the interpreted hydrogeology indicate portions of Plume A flow underneath and discharge to Diamond Creek.

Plume A contributes to Diamond Creek, which has no TCE regulatory limit due to its 3B Classification. Modeling demonstrates that the contaminant load to Diamond Creek from Plume A is not significant enough to require surface water treatment. There is no surface water treatment option included for Plume A because the contribution of TCE to Diamond Creek is not expected to lead to exceedances of any surface water standards.

PLUME A SUMMARY OF REMEDIAL ALTERNATIVES

Table 2 summarizes the remedial alternatives for Plume A, with the preferred alternatives in bold text.

Table 2 – PLUME A – REMEDIAL ALTERNATIVE SUMMARY TABLE

Alternative	Description	Timeframe to Achieve Surface Water RAOs (Years)	Timeframe to Achieve Groundwater RAOs (Years)	Capital Costs	Total O&M Cost	Average Annual O&M Cost	Present Value Cost
1A	No Further Action	NA	50	NA	NA	NA	$0
2A	LUCs[1]	NA	50	$18,484	$119,350	$2387	$61,181
3A	**MNA**	**NA**	**50**	**$0**	**$2,616,440**	**$52,329**	**$1,133,542**
4A	Groundwater Extraction and Treatment	NA	20	$2,038,778	$9,608,942	$480,447	$7,379,022
5A	Localized Bioaugmentation and MNA	NA	35	$11,756,353	$2,324,076	$66,402	$12,284,520
1A-INT	No Further Action	NA	120	NA	NA	NA	$0
2A-INT	LUCs[1]	NA	120	$0	$119,350	$994.58	$4,000
3A-INT	**MNA**	**NA**	**120**	**$0**	**$4,452,780**	**$37,106**	**$734,761**
4A-INT	Localized Chemical Oxidation and MNA	NA	110	$1,906,675	$3,623,598	$32,942	$2,479,258

RAO – Remedial Action Objective
O&M – Operation and Maintenance
NA – Not applicable
LUC – Land Use Controls
MNA – Monitored Natural Attenuation
INT – Intermediate

[1]LUCs are a component of all remedies with the exception of Alternative 1 (No Further Action).

Alternatives 1A and 1A-INT – No Action

Regulations governing the Superfund program require that a "no action" alternative be evaluated to establish a baseline for comparison. The No Action Alternative assumes no further action will be taken regarding contaminants in groundwater. No LUCs, such as legal/management control or LTM, would be implemented. The No Action alternative is not included in further detailed discussions for any of the remaining plumes of Zone D, as it does not meet one or more of the threshold criteria.

Alternatives 2A and 2A-INT – LUCs

LUCs are administrative, engineering, and/or physical controls to protect human health and the environment by controlling access and exposure to contaminants. LUCs are kept in place until unrestricted use and unlimited exposure can be allowed. The LUCs are made part of the Base General Plan and relate to the planning and development process to prevent exposure. In this case, the controls would generally prohibit use of the groundwater or surface water except for environmental monitoring and require sub-slab vapor venting systems in all new construction located over the contaminated groundwater plumes. The USAF is responsible for implementation, annual monitoring, and maintenance of the LUCs. Any changes to the Base General Plan, land use, or LUCs will require agreement of EPA and the WDEQ.

Discussions of LUCs as stand-alone remedies for the remaining plumes are not necessary, as one or more of the threshold criteria are not met. LUCs are a component of all remedies with the exception of Alternative 1 (No Action) to limit access/future use of groundwater and mitigate risk from indoor air if buildings are constructed overlying the groundwater plumes.

Alternatives 3A and 3A-INT – MNA

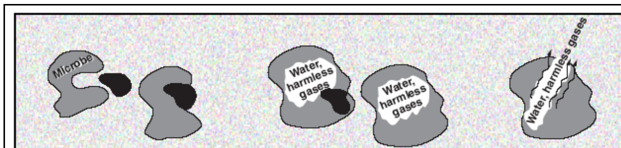
MNA makes use of in-place natural processes to contain the spread of contamination from chemical spills and reduce the concentration and amount of pollutants at contaminated sites. Environmental contaminants are left in place to allow for natural physical, biological, and chemical processes to occur and reduce contaminant concentrations to acceptable levels (e.g., the MCLs). The natural attenuation is documented through a monitoring program.

Alternative 4A – Groundwater Extraction and Treatment

Groundwater extraction and treatment involves the extraction of contaminated groundwater, treatment above ground to remove VOCs, and discharge of the treated groundwater. Extraction systems typically consist of a network of extraction points (e.g., wells) and a collection and conveyance system. For cost estimating purposes, a two-phase system that extracts both groundwater and vapor was proposed and the extracted groundwater would be treated with a combination of granular activated carbon for the liquid phase and a bioreactor for the vapor phase.

Alternative 5A – Localized Bioaugmentation and MNA

Bioaugmentation would remediate local high contaminant concentration areas in groundwater (generally 50 to 100 µg/L for Plume A), followed by MNA to reduce concentrations in the plume. Bioaugmentation is the addition of laboratory-grown microbes to a system to perform a specific type of remediation (Figure 4). The process of bioaugmentation has been used for decades in industrial operations such as food production and wastewater treatment. Adding microbes to contaminated groundwater systems for the purpose of remediation is an increasingly accepted technology that is currently being implemented at hazardous waste sites.



Microbe eats contaminant; Microbe digests contaminant and changes it to water and harmless gases; Microbe releases water and harmless gases into soil or groundwater (adapted from EPA Citizen's Guide to Bioremediation)

FIGURE 4 - BIOAUGMENTATION

Bioaugmentation in Zone D would require that microbes be injected into the subsurface. Before the injection of the microbes, anaerobic (low-oxygen) conditions must be established in the aquifer to maintain and support cell growth. This is accomplished by injecting supplements into the groundwater that in effect removes the available oxygen. Under ideal conditions, the introduced species will thrive, creating a population of microbes able to degrade site-specific contaminants to ethene. Ethene is a relatively inert compound that is non-toxic.

The microbes would continue to grow in the injected area creating zones of treatment. Although microbes can move within aquifers, the rate of movement is typically slower than natural movement of the groundwater. Therefore, the extent of the microbes is most likely dependent on the distribution of supplements (e.g., mixed oxygen scavenger solution, dissolved electron donors, and contaminants).

Alternative 4A-INT – Localized Chemical Oxidation and MNA

This option includes chemical oxidation in areas with TCE concentrations from approximately 70 to 80 µg/L, followed by MNA, to treat low level TCE concentrations (from 5 to 70 µg/L) in the intermediate groundwater zone of Plume A. The highest TCE concentration level in the intermediate zone was 81.6 µg/L in MW-165B sampled in 2001. Chemical oxidation consists of delivery of a chemical oxidant to contaminated media (groundwater or soil) to destroy the contaminants or convert them to harmless compounds commonly found in natural settings. This process breaks the carbon-carbon bonds in chlorinated VOCs such as TCE, DCE, and vinyl chloride. A Treatability Study was successfully performed for chemical oxidation at Zone D using potassium permanganate ($KMnO_4$) and therefore, this oxidant technology was selected for cost estimation purposes.

In general, studies have demonstrated that $KMnO_4$ may be more effective at treating moderate to low levels of dissolved groundwater contamination (less than 1,000 µg/L of TCE) rather than sorbed-phase contamination (attached to soil properties) located in source areas. Multiple applications of $KMnO_4$ may be required to offset the effects of soil oxidant demand and adsorption. The oxidant is consumed during oxidation of other naturally occurring compounds in the soil such as sulfide, metals, or total organic carbon.

Table 3 summarizes the evaluation criteria for assessing Superfund remedial alternatives.

Table 3 – EVALUATION CRITERIA FOR SUPERFUND REMEDIAL ALTERNATIVES

Threshold Criteria – Criteria must be met before an alternative can be considered as a remedy	**Overall Protection of Human Health and the Environment** describes how an alternative eliminates, reduces, or controls threats to public health and the environment through LUCs, engineering controls, or treatment.
	Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) evaluates whether the alternative meets federal and state environmental statutes, regulations, and other requirements that pertain to the site, or whether a waiver is justified.
Balancing Criteria – Relative tradeoffs between different criteria are evaluated	**Long-Term Effectiveness and Permanence** considers the ability of an alternative to maintain protection of human health and the environment over time.
	Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment evaluates an alternative's use of treatment to reduce the harmful effects of the principal contaminants, their ability to move in the environment, and the amount of contamination present.
	Short-term Effectiveness considers the length of time needed to implement an alternative and the risks the alternative poses to workers, residents, and the environment during implementation.
	Implementability considers the technical and administrative feasibility of implementing the alternative, including factors such as the relative availability of goods and services.
	Costs includes estimated capital and annual operations and maintenance costs, as well as present worth cost. Present worth cost is the total cost of an alternative over time in terms of today's dollar value. Cost estimates are expected to be accurate within a range of +50 to –30 percent.
Modifying Criteria – Evaluate whether remedy is supported by state and community after the public comment period	**State/Support Agency Acceptance** considers whether the State agrees with or opposes the preferred alternative. WDEQ reviews and comments upon all important documents throughout the process.
	Community Acceptance considers whether the local community agrees with or opposes the preferred alternative. Comments received on the Proposed Plan are an important indicator of community acceptance.

PLUME A EVALUATION OF ALTERNATIVES

In accordance with EPA guidance, the nine criteria listed in Table 3 - Evaluation Criteria for Superfund Remedial Alternatives, were used to evaluate the alternatives individually and against each other to aid in selecting a remedy. This section of the Proposed Plan summarizes the relative performance of each alternative against the nine criteria, noting how each compares to the other options under consideration.

1. Overall Protection of Human Health and Environment

All of the Plume A alternatives except the “No Action” Alternatives would provide adequate protection of human health and the environment by eliminating, reducing, or controlling risk through treatment, engineering controls, and/or LUCs. Because the “No Action” Alternatives (1A and 1A-INT) are not protective of human health and the environment, they were eliminated from consideration.

2. Compliance with ARARs

Alternatives 3A, 4A, 5A, 3A-INT, and 4A-INT would meet their respective ARARs from Federal and State laws. Alternatives 2A and 2A-INT would not comply with potential chemical-specific ARARs because there is no means of monitoring plume attenuation. Because Alternatives 2A and 2A-INT would not comply with ARARs, they were eliminated from consideration.

3. Long-term Effectiveness and Permanence

Shallow Zone: Alternatives 3A, 4A, and 5A include LUCs that would limit or prevent use of groundwater and continued monitoring would provide a reliable means to assess the treatment effectiveness. Alternative 3A uses natural processes that would reduce contaminant levels in groundwater to MCLs over 50 years. Continued monitoring would provide a reliable means to assess the residual concentrations and manage the risk posed by the residual. The Alternative 3A process would produce no residual contamination and minimal O&M of wells and groundwater sampling are required.

Treatment under Alternative 4A would reduce the TCE concentration in groundwater to the MCL in approximately 20 years. Continued monitoring and LUCs would provide a reliable means to assess the treatment effectiveness. Activated carbon would contain the TCE; however, it would be shipped off site for destruction through regeneration. There are greater O&M requirements during the 20-year treatment period under Alternative 4A.

Under Alternative 5A, in-place treatment would reduce the TCE concentration to MCLs in treated groundwater areas in approximately 10 years. Natural processes would reduce the remaining untreated TCE groundwater concentrations to the MCL approximately 25 years after completion of treatment giving a total cleanup time of 35 years. Continued monitoring provides a reliable means to assess the treatment effectiveness and there would be no untreated residual contamination. There are greater O&M requirements only during the 10-year treatment period.

Intermediate-Depth Zone: Alternatives 3A-INT and 4A-INT include LUCs that would limit or prevent use of groundwater and continued monitoring would provide a reliable means to assess the treatment effectiveness.

Alternative 3A-INT relies on natural processes that will reduce contaminant levels in groundwater to MCLs in 120 years. Continued monitoring and LUCs provide a reliable means to assess the residual concentrations and manage the risk posed by the residual. The Alternative 3A-INT process would produce no residual contamination and minimal O&M of wells and groundwater sampling are required.

Alternative 4A-INT employs active treatment to reduce the TCE concentrations in groundwater to 50 µg/L in approximately six months. Natural processes will then reduce the TCE concentration in groundwater to the MCL after completion of active treatment. This will take approximately 110 years in Plume A. Continued monitoring provides a reliable means to assess the treatment effectiveness. There are slightly greater O&M requirements only during the six-month treatment period when active treatment is being performed.

4. Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Shallow Zone: Alternative 3A reduces toxicity, mobility, and volume of TCE via natural attenuation of contaminants in groundwater and no residuals would be present in groundwater at completion. Alternative 4A reduces toxicity, mobility, and volume of TCE via treatment of groundwater and natural processes. TCE, contained in activated carbon, would be shipped off site for destruction through regeneration. Alternative 5A reduces toxicity, mobility, and volume of TCE via in-place treatment of groundwater and natural processes. Alternatives 3A, 4A, and 5A all reduce TCE concentrations in groundwater to MCLs through irreversible processes.

Intermediate-Depth Zone: TCE levels in groundwater are reduced to MCLs through irreversible processes under Alternatives 3A-INT and 4A-INT. Alternative 3A-INT reduces the toxicity, mobility, and volume of TCE over time from natural attenuation of contaminants in groundwater. Alternative 4A-INT will reduce toxicity, mobility, and volume over time from active treatment of groundwater and natural processes. No residuals are expected to be present in groundwater at completion of Alternatives 3A-INT or 4A-INT.

5. Short-term Effectiveness

Shallow Zone: There would be no additional risk to site workers and the environment for Alternatives 3A. During construction activities under Alternatives 4A and 5A there would be minimal additional risk to site construction workers and the environment. None of these three alternatives would present an increased risk during the implementation phase (after construction) to workers, the community, or the environment. For Alternative 4A, transport of spent carbon vessel to offsite regeneration facility would pose minimal risk to the community.

Alternative 4A would be effective in achieving the RAOs in the shortest period (20 years; 35 and 50 years for Alternatives 5A and 3A, respectively).

Intermediate-Depth Zone: Alternative 3A-INT presents no additional risk to site workers and the environment because there is no construction of a treatment system. Time to achieve MCLs within the plume is approximately 120 years.

During construction, there would be minimal additional risk to site construction workers and the environment for Alternative 4A-INT. However, as in Alternative 3A-INT, there would be no increased risk to workers, the community, or the environment during the implementation phase of Alternative 4A-INT after construction. Alternative 4A-INT would be effective in achieving the RAOs in 110 years for Plume A.

6. Implementability

Shallow Zone: Alternatives 3A, 4A, and 5A can be technically and administratively implemented. However, there are important technical uncertainties that differentiate the ability to effectively implement each alternative. Alternative 3A is the most efficient to implement and schedule delays are not likely. Passive treatment used under Alternative 3A does not require removal, aboveground treatment, or treatment, storage, and disposal (TSD) services. Monitoring the effectiveness of Alternative 3A is simple. F. E. Warren administrative requirements include modifying the General Plan and preparing an LTM Plan.

Alternative 4A would be moderately easy to implement. Carbon adsorption is a proven and reliable technology. Carbon equipment (vessels, pumps) and regeneration services are readily available. Conventional construction techniques would be used and schedule delays are not likely. Monitoring the effectiveness is simple. Administrative requirements include preparation of a treatment system design, O&M Plan, LTM Plan, and modifying the General Plan.

Bioaugmentation (Alternative 5A) has not been tested at F. E. Warren. However, a treatability study would be performed as part of a pre-design investigation to test this technology's applicability to Zone D groundwater. Bioaugmentation materials (microbes, electron donors) are readily available. Conventional well drilling and well installation techniques would be used and would not create schedule delays. Monitoring the effectiveness is simple. Multiple drilling contractors are available, so competitive bids can be obtained. Administrative requirements include preparation of a treatment system design, O&M Plan, LTM Plan, and modifying the General Plan.

Intermediate-Depth Zone: Alternatives 3A-INT and 4A-INT are easy to implement and schedule delays are not likely. Monitoring the effectiveness of each of these two alternatives is simple. Alternatives 3A-INT and 4A-INT rely on processes that do not require removal, aboveground treatment or TSD services. F. E. Warren administrative requirements include modifying the General Plan and preparing an LTM Plan.

Alternative 4A-INT employs chemical oxidation, which is a proven and reliable technology. The chemical oxidant ($KMnO_4$) is readily available. Conventional well drilling and installation techniques would be used. Multiple drilling contractors and $KMnO_4$ suppliers are available and competitive bids can be obtained. Administrative requirements for Alternative 4A-INT include preparation of a treatment system design and LTM Plan, and modifying the General Plan.

7. Costs

Costs are presented in Table 2, Plume A– Remedial Alternative Summary.

8. State/Support Agency Acceptance

EPA and the WDEQ support the preferred alternative: Alternative 3A/3A-INT (MNA).

9. Community Acceptance

Community acceptance of the preferred alternative will be evaluated after the public comment period ends and will be discussed in the ROD for the site.

PLUME A SUMMARY OF THE PREFERRED ALTERNATIVE

The preferred alternative for cleaning up Plume A is Alternative 3A/3A-INT. This remedy consists of natural biological, chemical, and physical processes that reduce contaminant mass, toxicity, mobility, volume, and concentration without the application of actively engineered remediation techniques.

MNA in the shallow zone occurs in a reasonable time frame given the circumstances of the site and at a moderate cost. Groundwater sampling data indicate natural attenuation is already occurring within Plume A, as groundwater sampling data indicates TCE concentrations are decreasing over time. Treatment options to reduce the time frame provide relatively small reductions in time for large increases in cost. All of the time frames for the intermediate zone are comparable in length. In order to get a very small reduction in time, a large cost increase would be needed and is not justified by site conditions. Groundwater modeling results for these alternatives (3A/3A-INT) indicate shallow and intermediate zone groundwater will be remediated to the MCL in approximately 50 and 120 years, respectively.

SS7

SS7 NATURE AND EXTENT

TCE concentrations in shallow groundwater at SS7 range as high as 13,170 µg/L. A consistent trend in the distribution of TCE concentrations at SS7 is not apparent. *Cis*-DCE was detected in wells ranging from 1.8 µg/L to 282 µg/L, with two wells exceeding the MCL of 70 µg/L. The presence and distribution of *cis*-DCE suggests that biodegradation may be occurring. Vinyl chloride has been reported in wells downgradient of the existing PRB at concentrations as high as 107 µg/L in 2001. There were no reported concentrations prior to installation of the PRB. The occurrence of vinyl chloride is believed to be related to in-place breakdown of TCE associated with the changed geochemical conditions created downgradient of the PRB.

Modeling indicated that a north-south groundwater divide exists along the western third of the site. West of this divide, groundwater flows toward Diamond Creek in the stream reach between surface water monitoring stations D3 and D3.5 (Figure 3). Analytical data from the LTM Program at SS7 indicate that the PRB is working as designed; however, shallow zone groundwater along the western third of the site is flowing toward Diamond Creek and not through the wall. Therefore, other technologies were evaluated to treat the shallow zone in this portion of SS7.

SS7 SUMMARY OF REMEDIAL ALTERNATIVES

Table 4 summarizes the remedial alternatives for SS7 with the preferred alternatives in bold text. Only alternatives which propose a technology or combination of technologies not previously described are presented.

Alternative 3S – Existing PRB and MNA

A PRB is an emplacement of reactive treatment materials in the subsurface designed to intercept a contaminant plume. The PRB provides a preferential flow path through the reactive media and the contaminant(s) are chemically transformed into environmentally inert compounds to attain the RAOs. Figure 5 depicts how a PRB functions.

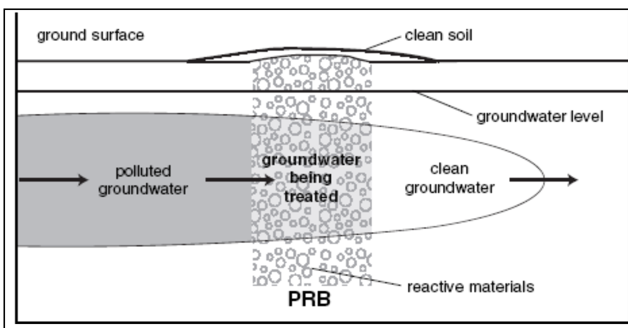


FIGURE 5 – SCHEMATIC OF PRB OPERATION (from EPA's Citizen's Guide)

The existing PRB extends to a depth of 15 feet below the water table along a length of 568 feet of Diamond Creek between surface monitoring stations D3.5 and D3.6. The reactive media is ZVI. Groundwater sampling data and numerical modeling results suggest that the SS7 plume is relatively stable and contaminant mass has not been significantly reduced upgradient of the existing PRB. VOC concentrations downgradient of the PRB are slowly decreasing, from the PRB toward Diamond Creek. Based on these results, continued use of the SS7 PRB, together with MNA, is considered to be a viable alternative. The PRB would need to be replaced after 30 and 60 years based on the current understanding of the longevity of the ZVI reactivity. However, there is a high degree of uncertainty with this timeframe because the technology has only been around for approximately 10 years.

Alternative 4S – Expansion of PRB, West PRB, and MNA

This alternative entails expanding the existing PRB, constructing a new PRB along the western side of SS7, and MNA to remediate the remainder of the SS7 plume. The PRB would need to be replaced after 30 and 60 years.

Alternative 5S – Existing PRB, Localized Bioaugmentation, and MNA

The existing PRB would continue to protect the surface water interface of SS7 with Diamond Creek and treat shallow groundwater. This in conjunction with bioaugmentation and MNA would treat the chlorinated VOC contamination in groundwater upgradient of the PRB. Replacement of the existing PRB would not be necessary due to the treatment of VOCs upgradient of the PRB by bioaugmentation.

Table 4 – SS7 – REMEDIAL ALTERNATIVE SUMMARY TABLE

Alternative	Description	Timeframe to Achieve Surface Water RAOs (Years)	Timeframe to Achieve Groundwater RAOs (Years)	Capital Costs	Total O&M Cost	Average O&M Cost	Present Value Cost
1S	No Further Action	NA	100	NA	NA	NA	$0
2S	LUCs[2]	NA	100	$18,484	$238,700	$2387	$64,981
3S	Existing PRB and MNA	NA[1]	100	$6,085,270	$4,565,970	$45,660	$1,918,270
4S	Extend Existing PRB, West PRB, and MNA	NA[1]	100	$15,332,154	$4,565,970	$45,660	$4,617,360
5S	**Existing PRB, Bioaugmentation, and MNA**	**NA[1]**	**35**	**$2,478,272**	**$2,284,053**	**$65,259**	**$3,467,083**
6S	ERH, Chemical Oxidation, and Discount Existing PRB	NA[1]	85	$7,942,981	$4,045,636	$47,596	$8,766,749
1S-INT	No Further Action	NA	290	NA	NA	NA	$0
2S-INT	LUCs[2]	NA	290	$0	$167,090	$576	$245
3S-INT	MNA	NA	290	$0	$11,447,165	$39,473	$741,263
4S-INT	**Chemical Oxidation and MNA**	**NA**	**175**	**$592,380**	**$5,244,772**	**$29,970**	**$1,219,615**
Surface Water	**Channel Drop Structures**	**NA[1]**	**NA**	**$60,000**	**NA**	**NA**	**$60,000**

RAO – Remedial Action Objective
O&M – Operation and Maintenance
NA – Not applicable
LUC – Land Use Controls
MNA – Monitored Natural Attenuation
INT – Intermediate

[1] TCE-contaminated groundwater at SS7 discharges to Diamond Creek (Class 3B stream; no TCE standards). However, discharge of Diamond Creek to Crow Creek (Class 2AB stream; TCE standard = 2.7 µg/L) can potentially lead to TCE exceedances in Crow Creek. Therefore, an indirect action is proposed to lower TCE concentrations in Diamond Creek.

[2] LUCs are a component of all remedies with the exception of Alternative 1 (No Further Action) to limit.

Alternative 6S - ERH with SVE and Chemical Oxidation

This alternative utilizes ERH (electrical resistance heating) technology to treat the highest concentration areas of chlorinated VOCs in groundwater (greater than 2,000 μg/L) in conjunction with chemical oxidation for the remainder of the SS7 plume. Contaminants would be treated in the subsurface by passing an electrical current through the soil and groundwater. Heat would cause the soil vapors to become steam. Because the boiling points of TCE and its degradation products are close to that of water, the water particles and contaminants volatize. Vapor recovery wells allow for contaminant removal. Figure 6 displays a schematic of an ERH system.

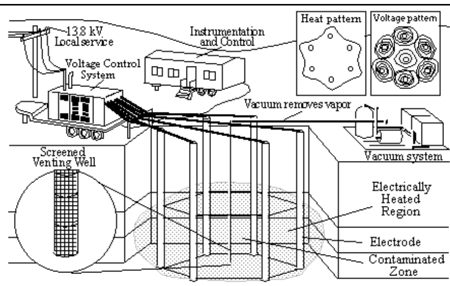


FIGURE 6 – SCHEMATIC OF ERH
(from the Federal Remediation Technologies Roundtable website http://www.frtr.gov)

This technology is capable of reducing contaminant concentrations to below MCLs. For cost estimating purposes, Fenton's Reagant is the chemical oxidant that was planned for the intermediate VOC concentrations (1,000 to 2,000 μg/L) and $KMnO_4$ for the lower concentrations (approximately 100 to 1,000 μg/L). Fenton's Reagant is a chemical oxidant that is injected into the subsurface to treat dissolved contaminants or those that are attached to soil particles (i.e., adsorbed). Like $KMnO_4$, multiple applications may be required to achieve treatment goals. The preferred oxidant would be selected during the design phase.

The existing PRB would be incompatible with the ERH technology proposed for this alternative. The ERH technology is comparatively costly and typically applied only to localized, high concentration areas (greater than 1,000 µg/L at SS7).

Surface Water Treatment - Channel Drop Structures

To reduce the indirect impact of TCE concentrations in Diamond Creek on Crow Creek, indirect actions that would allow increased aeration and volatilization of the TCE in Diamond Creek were considered. Increasing aeration would cause a higher rate of volatilization of the TCE, and thus reduce the amount of TCE in the creek. Technologies evaluated included an instream fountain, an indoor water cascade, an instream bubbler, and channel drop structures. Channel drop structures were selected for aeration of Diamond Creek during the FS due to this technology's relative simplicity, low level of intrusion on the environment, and low cost.

Channel drop structures are weir-type panels that are placed in the streambed to allow a small area of pooling prior to an overflow (Figure 7). The overflow is obstructed with a concrete slope embedded with rocks to allow for the creation of turbulence in the water. The turbulence created by the flow of the water over the rocks allows additional aeration to stream flow due to the increased surface area of the water.

FIGURE 7 – EXAMPLE OF A CHANNEL DROP STRUCTURE

The design and construction of such a structure is relatively simple and this type of structure is relatively low in cost, would require very little maintenance, and would not require an outside power source. If the required amount of aeration was not achieved initially as determined from analytical results in surface water downgradient of the structure, an additional channel drop structure could be readily installed. Although there are limited areas with adequate gradient for the installation of such a structure in Diamond Creek, it is anticipated that no more than three to four would be needed.

Four of these structures are estimated to cost $60,000. This cost would be added to the alternative costs associated with treatment of groundwater. The required O&M for this option would be weekly inspection and removal of flow impedances in the weir until the RAOs are achieved.

SS7 EVALUATION OF ALTERNATIVES

This section of the Proposed Plan summarizes the relative performance of each alternative against the nine criteria presented in Table 3.

1. Overall Protection of Human Health and Environment

All of the SS7 alternatives except the "No Action" Alternatives would provide adequate protection of human health and the environment by eliminating, reducing, or controlling risk through treatment, engineering controls, and/or LUCs. Because the "No Action" Alternatives (1S and 1S-INT) are not protective of human health and the environment, they were eliminated from consideration.

2. Compliance with ARARs

Alternatives 3S, 4S, 5S, 6S, 3S-INT, and 4S-INT would meet their respective ARARs from Federal and State laws. Alternatives 2S and 2S-INT would not comply with potential chemical-specific ARARs because there is no means of monitoring plume attenuation. Because Alternatives 2S and 2S-INT would not comply with ARARs, they were eliminated from consideration.

3. Long-term Effectiveness and Permanence

Shallow Zone: Alternatives 3S, 4S 5S, and 6S include LUCs which would limit or prevent use of groundwater and continued monitoring would provide a reliable means to assess the treatment effectiveness.

Under Alternative 3S, the existing PRB (and replacements at 30 and 60 years) would continue to treat groundwater that is migrating from areas upgradient of the PRB where concentrations of TCE greater than 1,000 µg/L occur. This treatment would continue for as long as 100 years. Within 20 years, the residual TCE concentrations in groundwater downgradient of the PRB (attributed to desorption) would have diminished to less than 50 µg/L leading to reduction in contaminant loading to Diamond Creek. In the remainder of the groundwater plume, natural processes would reduce contaminant levels to MCLs in approximately 100 years. No untreated residual contamination would be produced by the Alternative 3S process and minimal O&M of wells and groundwater sampling would be required.

For Alternative 4S, treatment by the PRBs combined with natural attenuation processes would reduce the TCE concentration to the MCL in approximately 100 years. The same assumptions as Alternative 3S for PRB replacement and downgradient contaminant reduction apply to Alternative 4S.

For Alternative 5S, treatment by downgradient groundwater flow through the existing PRB will reduce the TCE concentration near Diamond Creek. Bioaugmentation will reduce the TCE concentration in the treated areas to the MCL in approximately 20 years and natural processes will reduce the TCE groundwater concentration in the remainder of the plume to the MCL in an additional 15 years.

Alternative 6S uses in-place treatment by ERH in areas with TCE concentrations greater than 1,000 µg/L and chemical oxidation in most of the remainder of the SS7 plume. The TCE concentration in these treated areas would be reduced to MCLs in approximately six months. Natural processes would reduce the remaining TCE concentrations to the MCL in approximately 85 years.

Intermediate-Depth Zone: Alternatives 3S-INT and 4S-INT include LUCs that would limit or prevent use of groundwater and continued monitoring would provide a reliable means to assess the treatment effectiveness.

Alternative 3S-INT has natural processes which will reduce contaminant levels in groundwater to MCLs over time. TCE groundwater concentrations would be reduced to the MCL in approximately 290 years. Continued monitoring and LUCs provide a reliable means to assess the residual concentrations and manage the risk posed by the residual. No untreated residual contamination would be produced by the Alternative 3S-INT treatment process and minimal O&M of wells and groundwater sampling are required.

Alternative 4S-INT employs active treatment to reduce the TCE concentrations in groundwater to 50 µg/L in approximately six months. Natural processes will reduce the TCE concentration in groundwater to the MCL after completion of active treatment. This will take approximately 175 years in SS7. Continued monitoring provides a reliable means to assess the treatment effectiveness. Slightly greater O&M is required only during the active six-month treatment period.

4. *Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment*

Shallow Zone: Alternatives 3S, 4S, 5S, and 6S reduce the toxicity, mobility, and volume of TCE over time through treatment of groundwater and natural processes. No treatment residuals are expected to be present in groundwater at completion. These four alternatives reduce TCE concentrations in groundwater to the MCL through irreversible processes.

Intermediate-Depth Zone: TCE levels in groundwater are reduced to MCLs through irreversible processes under Alternatives 3S-INT and 4S-INT. Alternative 3S-INT reduces the toxicity, mobility, and volume of TCE over time from natural attenuation of contaminants in groundwater. Alternative 4S-INT will reduce toxicity, mobility, and volume over time from active treatment of groundwater and natural processes. No residuals are expected to be present in groundwater at completion of Alternatives 3S-INT and 4S-INT.

5. *Short-term Effectiveness*

Shallow Zone: There would be no additional risk to site workers and the environment for Alternatives 3S - there is no construction of a treatment system. Alternatives 4S, 5S, and 6S would have minimal additional risk to site workers and the environment during construction. None of these four alternatives would present an increased risk to workers, the community, or the environment during implementation.

Alternative 5S would be effective in achieving the RAOs in the shortest period (35 years). Alternative 6S would achieve MCLs in approximately 85 years and Alternatives 3S and 4S in approximately 100 years.

Intermediate-Depth Zone: Alternative 3S-INT presents no additional risk to site workers and the environment as there is no construction of a treatment system. There would be no increased risk to workers, the community, or the environment during implementation of Alternative 3S-INT. Alternative 3S-INT would achieve MCLs in approximately 290 years.

During construction, there would be minimal additional risk to site workers and the environment for Alternative 4S-INT. However, as in Alternative 3S-INT, there would be no increased risk to workers, the community, or the environment during the implementation phase of Alternative 4S-INT, which would involve only groundwater sampling. Alternative 4S-INT would achieve MCLs in approximately 175 years.

6. *Implementability*

Shallow Zone: Alternative 3S is easiest to implement and schedule delays are not likely. The PRB and monitoring are already in place. However, replacement of the PRB would be necessary at 30 and 60 years. Alternative 3S does not require removal, aboveground treatment, or TSD services and monitoring effectiveness is simple. Administrative requirements include revisions to the General Plan and preparing an LTM Plan.

Alternatives 4S and 6S would be moderately easy to implement. PRBs (Alternative 4S) and chemical oxidation (Alternative 6S) are both proven and reliable technologies. ERH (Alternative 6S) has not been tested at F. E. Warren. ZVI required for Alternative 4S is readily available as are chemical oxidants and SVE equipment needed for Alternative 6S. Conventional well drilling and installation techniques would be used for both of these alternatives and schedule delays are not likely. Alternative 4S would require PRB replacements at 30 and 60 years. Monitoring the effectiveness of Alternatives 4S and 6S is simple. Administrative requirements for Alternative 4S include a preparation of a treatment system design and LTM Plan, and modifying the General Plan. Alternative 6S has the same administrative requirements with the addition of an O&M Plan.

Bioaugmentation (Alternative 5S) has not been tested at F. E. Warren. However, a treatability study would be performed as part of a pre-design investigation to test this technology's applicability to Zone D groundwater. Bioaugmentation materials (microbes, stimulants) and ZVI are readily available. Conventional well drilling and well installation techniques would be used and schedule delays are not likely. Monitoring the effectiveness is simple. Multiple drilling contractors are available, so competitive bids can be obtained. Administrative requirements include preparation of a treatment system design, LTM Plan, and modifying the General Plan.

Intermediate-Depth Zone: Alternatives 3S-INT and 4S-INT are easy to implement and schedule delays are not likely. Monitoring the effectiveness of each of these two alternatives is simple. Alternatives 3S-INT and 4S-INT rely on processes that do not require removal, aboveground treatment or TSD services. F. E. Warren administrative requirements include modifying the General Plan and preparing an LTM Plan.

Alternative 4S-INT employs chemical oxidation which is a proven and reliable technology. The chemical oxidant ($KMnO_4$) is readily available. Conventional well drilling and installation techniques would be used. Multiple drilling contractors and $KMnO_4$ suppliers are available and competitive bids can be obtained. Administrative requirements for Alternative 4S-INT include preparation of a treatment system design and LTM Plan, and modifying the General Plan.

7. Costs

Costs are presented in Table 3 SS7– Remedial Alternative Summary.

8. State/Support Agency Acceptance

EPA and the WDEQ support the preferred alternative: Alternative 5S/4S-INT (Existing PRB, Localized Bioaugmentation, chemical oxidation in the intermediate zone, and MNA for both zones of the plume).

9. Community Acceptance

Community acceptance of the preferred alternative will be evaluated after the public comment period ends and will be discussed in the ROD for the site.

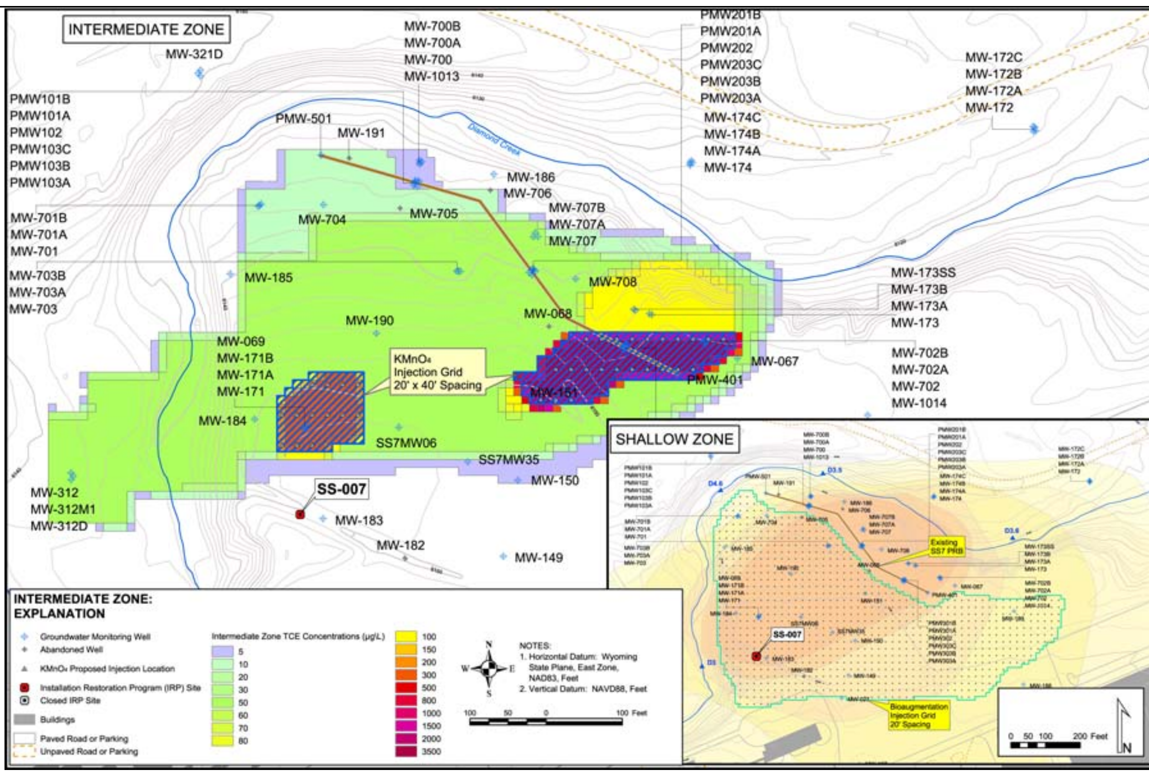


FIGURE 8 – CONCEPTUAL LAYOUT OF PREFERRED ALTERNATIVE FOR SS7

SS7 SUMMARY OF THE PREFERRED ALTERNATIVE

The preferred alternative for cleaning up the SS7 groundwater is Alternative 5S/4S-INT. This alternative includes a combination of the existing PRB, bioaugmentation to remediate portions of the shallow zone TCE plume, chemical oxidation at the intermediate zone, and MNA to treat TCE concentrations in the shallow and intermediate groundwater zones. A conceptual layout of the proposed remedy is illustrated in Figure 8. Areas targeted for active treatment represent optimized configurations as determined from multiple modeling scenarios.

Channel drop structures were selected to decrease concentrations of TCE in Diamond Creek, thereby decreasing Diamond Creek's contribution of TCE to Crow Creek.

The greater VOC concentrations in groundwater and their proximity to the creek merit more aggressive action at SS7. For the shallow zone, Alternative 5S is both the lowest cost and shortest time frame (although may include greater uncertainty surrounding bioaugmentation). Alternative 4S-INT still results in a long time frame for the intermediate zone, but is the only treatment alternative which reduces the time frame and substantially reduces concentrations and the associated risk in the immediate short term.

Bench scale and pilot scales are currently underway for the bioaugmentation technology at SS7. If results of these tests are favorable and if bioaugmentation in the intermediate zone would provide similar treatment and potentially allow for an economy of scale by utilizing common injection locations, the potential application of bioaugmentation to the intermediate zone could be re-evaluated.

Results of groundwater modeling suggest that TCE concentrations in shallow zone groundwater will attenuate to MCLs from present conditions in approximately 35 years with bioaugmentation. Chemical oxidation applied to the intermediate zone would actively treat the highest TCE concentrations in groundwater (generally 200 to 2,900 µg/L at SS7). Natural attenuation following the treatment would allow TCE concentrations in groundwater to achieve MCLs in 175 years. The combination of this treatment would reduce the total treatment time by nearly half of the 290-year MNA - option only for the intermediate zone.

PLUME B

PLUME B NATURE AND EXTENT

In Plume B, only TCE and *cis-DCE* were reported at concentration levels above the Wyoming Groundwater Standards and MCLs. Maximum concentrations of these contaminants are 102.7 and 123 µg/L, respectively. TCE concentrations decrease to below applicable standards between LF7 and Crow Creek. Therefore, the downgradient edge of the plume (as defined by the 5 µg/L isoconcentration) does not extend to Crow Creek. However, trace concentrations in groundwater (less than 5µg/L) are suspected to discharge into Crow Creek, a Class 2AB creek, which has a current regulatory limit of 2.7 µg/L. There has never been a documented exceedance of WDEQ surface water quality standards for Plume B and modeling demonstrates that no exceedances are expected.

PLUME B SUMMARY OF REMEDIAL ALTERNATIVES

Table 5 summarizes the remedial alternative for Plume B, with the preferred alternatives in bold text. All technologies pertaining to the Plume B alternatives have been previously described in prior plume-specific descriptions.

Table 5 – PLUME B – REMEDIAL ALTERNATIVE SUMMARY TABLE

Alternative	Description	Timeframe to Achieve Surface Water RAOs (Years)	Timeframe to Achieve Groundwater RAOs (Years)	Capital Costs	Total O&M Cost	Average O&M Cost	Present Value Cost
1B	No Further Action	0	65	NA	NA	NA	$0
2B	LUCs[1]	0	65	$18,484	$155,155	$2387	$63,341
3B	MNA	0	65	$0	$4,461,154	$68,633	$1,619,883
4B	Groundwater Extraction, Treatment, and MNA	0	30	$1,176,281	$6,783,913	$226,130	$5,361,029
5B	**Chemical Oxidation and MNA**	**0**	**35**	**$914,625**	**$3,247,947**	**$92,798**	**$2,391,476**
1B-INT	No Further Action	NA	110	NA	NA	NA	$0
2B-INT	LUCs[1]	NA	110	$0	$105,028	$954	$1,765
3B-INT	MNA	NA	110	$0	$3,912,184	$35,565	$700,323
4B-INT	**Localized Chemical Oxidation and MNA**	**NA**	**35**	**$1,500,411**	**$1,279,268**	**$36,551**	**$2,030,068**

RAO – Remedial Action Objective
LUC – Land Use Controls
O&M – Operation and Maintenance
MNA – Monitored Natural Attenuation
NA – Not applicable
INT – Intermediate

For Plume B, there has never been a documented exceedance of the WDEQ surface water quality standard for TCE and the loading calculations indicate that no exceedances are expected (refer to the FS). Therefore, a zero (0) has been used for the SW RAO timeframe.

[1]LUCs are a component of all remedies with the exception of Alternative 1 (No Further Action).

PLUME B EVALUATION OF ALTERNATIVES

In accordance with EPA guidance, the performance of each alternative is evaluated against the nine criteria listed in Table 3.

1. *Overall Protection of Human Health and Environment*

All of the Plume B alternatives except the “No Action” Alternatives would provide adequate protection of human health and the environment by eliminating, reducing, or controlling risk through treatment, engineering controls, and/or LUCs. Because the “No Action” Alternatives (1B and 1B-INT) are not protective of human health and the environment, they were eliminated from consideration.

2. *Compliance with ARARs*

Alternatives 3B, 4B, 5B, 3B-INT, and 4B-INT would meet their respective ARARs from Federal and State laws. Alternatives 2B and 2B-INT (LUCs) would not comply with potential chemical-specific ARARs as there is no means of monitoring plume attenuation. Because Alternatives 2B and 2B-INT would not comply with ARARs, they were eliminated from consideration.

3. *Long-term Effectiveness and Permanence*

Shallow Zone: Alternatives 3B, 4B, and 5B include LUCs which would limit or prevent use of groundwater and continued monitoring would provide reliable means to assess the treatment effectiveness.

Alternative 3B has natural processes that will reduce contaminant levels in groundwater to MCLs over time. TCE groundwater concentrations would be reduced to the MCL in approximately 65 years. Continued monitoring and LUCs provides a reliable means to assess the residual concentrations and manage the risk posed by the residual. No untreated residual contamination would be produced by the Alternative 3B process. Minimal O&M of wells and groundwater sampling is required.

Alternative 4B would reduce the TCE concentration in groundwater for the treated area to MCLs in approximately 10 years. Natural processes would reduce the remaining TCE concentrations in groundwater to the MCL approximately 20 years after completion of *ex-situ* treatment. Continued monitoring provides a reliable means to assess the treatment effectiveness. Activated carbon would contain the TCE; however, it would be shipped off site for destruction through regeneration. There would be greater O&M only during 10-year treatment period.

Alternative 5B includes active treatment that will reduce the TCE concentration in groundwater to 50 µg/L in approximately six months. Natural processes will reduce the TCE concentration in groundwater to the MCL approximately 35 years after completion of active treatment. Continued monitoring provides a reliable means to assess the treatment effectiveness. Greater O&M would be required only during six-month active treatment period.

Intermediate-Depth Zone: Alternatives 3B-INT and 4B-INT include LUCs which would limit or prevent use of groundwater and continued monitoring would provide reliable means to assess the treatment effectiveness.

Alternative 3B-INT has natural processes which will reduce contaminant levels in groundwater to MCLs over time. Continued monitoring and LUCs provide a reliable means to assess the residual concentrations and manage the risk posed by the residual. No residual contamination would be produced by the Alternative 3B-INT process and minimal O&M of wells and groundwater sampling are required.

Alternative 4B-INT employs active treatment to reduce the TCE concentrations in groundwater to 50 µg/L in approximately six months. Natural processes will reduce the TCE concentration in groundwater to the MCL after completion of active treatment. This will take approximately 35 years in Plume B. Continued monitoring provides a reliable means to assess the treatment effectiveness. Greater O&M is required only during six-month treatment period.

4. Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Shallow Zone: TCE levels in groundwater are reduced to MCLs through irreversible processes under Alternatives 3B, 4B, and 5B. Alternative 3B reduces the toxicity, mobility, and volume of TCE over time from natural attenuation of contaminants in groundwater with no residuals present in groundwater at completion. Alternative 4B reduces toxicity, mobility, and volume of TCE over time from *ex-situ* treatment of groundwater and natural processes. TCE is adsorbed to activated carbon and destroyed in the bioreactor. Alternative 5B reduces TCE toxicity, mobility, and volume over time from active treatment of groundwater and natural processes.

Intermediate-Depth Zone: TCE levels in groundwater are reduced to MCLs through irreversible processes under Alternatives 3B-INT and 4B-INT. Alternative 3B-INT reduces the toxicity, mobility, and volume of TCE over time from natural attenuation of contaminants in groundwater. Alternative 4B-INT will reduce toxicity, mobility, and volume over time from active treatment of groundwater and natural processes. No residuals are expected to be present in groundwater at completion of Alternatives 3B-INT and 4B-INT.

5. Short-term Effectiveness

Shallow Zone: There would be no additional risk to site workers and the environment for Alternatives 3B - there is no construction of a treatment system. Under Alternatives 4B and 5B there would be minimal additional risk to site workers and the environment during construction. None of these three alternatives would present an increased risk to workers, the community, or the environment during implementation. For Alternative 4B, transport of spent carbon vessels to an off-site regeneration facility would pose minimal risk to the community.

Alternative 4B would be effective in achieving the RAOs in the shortest period (30 years). Alternatives 3B and 5B would achieve MCLs in approximately 65 and 35 years, respectively.

Intermediate-Depth Zone: Alternative 3B-INT presents no additional risk to site workers and the environment because there is no construction of a treatment system. There would be no increased risk to workers, the community, or the environment during implementation of Alternative 3B-INT. Time to achieve MCLs for Plume B is approximately 110 years.

There would be minimal additional risk to site workers and the environment during construction for Alternative 4B-INT. As in Alternative 3B-INT, there would be no increased risk to workers, the community, or the environment during implementation of Alternative 4B-INT. Alternative 4B-INT would be effective in achieving the RAOs in 35 years for Plume B.

6. Implementability

Shallow Zone: Alternatives 3B and 5B are both easy to implement and schedule delays are not likely. Monitoring effectiveness is simple for both of these alternatives. Alternative 3B relies on passive processes that do not require removal, aboveground treatment, or TSD services. Administrative requirements for Alternative 3B include modifying the General Plan. Alternative 5B includes chemical oxidation, which is a proven and reliable technology. The chemical oxidant is readily available. Conventional well drilling and installation techniques would be used and multiple contractors are available. Competitive bids can be obtained. Administrative requirements for Alternative 5B include preparation of a treatment system design and LTM Plan, as well as modifying the General Plan.

Alternative 4B would be moderately easy to implement. Carbon adsorption is a proven and reliable technology and carbon equipment (vessels, pumps) and regeneration services are readily available. Conventional construction techniques would be used and schedule delays are not likely. Monitoring the effectiveness is simple.

Administrative requirements include preparation of both an O&M Plan and LTM Plan, and modifying the General Plan.

Intermediate-Depth Zone: Alternatives 3B-INT and 4B-INT are easy to implement and schedule delays are not likely. Monitoring the effectiveness of each of these two alternatives is simple. Alternatives 3B-INT and 4B-INT rely on processes that do not require removal, aboveground treatment or TSD services. F. E. Warren administrative requirements include modifying the General Plan and preparing an LTM Plan.

Alternative 4B-INT employs chemical oxidation which is a proven and reliable technology. The chemical oxidant ($KMnO_4$) is readily available. Conventional well drilling and installation techniques would be used. Multiple drilling contractors and $KMnO_4$ suppliers are available and competitive bids can be obtained. Administrative requirements for Alternative 4B-INT include preparation of a treatment system design and LTM Plan, and modifying the General Plan.

7. Costs

Costs are presented in Table 4 Plume B – Remedial Alternative Summary.

8. State/Support Agency Acceptance

EPA and the WDEQ support the preferred alternative for Plume B: Alternative 5B/4B-INT (chemical oxidation treatment at both the shallow and intermediate zones, followed by MNA).

9. Community Acceptance

Community acceptance of the preferred alternative will be evaluated after the public comment period ends and will be discussed in the ROD for the site.

PLUME B SUMMARY OF THE PREFERRED ALTERNATIVE

The preferred alternative for treating Plume B groundwater is Alternative 5B/4B-INT. This remedy consists of the delivery of a chemical oxidant to the contaminated media of both the shallow and intermediate zones of Plume B. Natural attenuation will continue to degrade contaminant concentrations to RAOs for both shallow and intermediate zones for a total clean-up time of 35 years. Groundwater sampling data and numerical modeling results indicate Plume B is relatively stable and shrinking in size and contaminant mass. A conceptual layout of the proposed remedy is illustrated in Figure 9.

Chemical oxidation in the shallow zone reduces the time frame by a little more than one half of the MNA time frame. The cost is less than double the cost of MNA and the overall cost is moderate. In the intermediate zone, chemical oxidation is about triple the cost of MNA but still in a moderate range. However, this cost increase results in a substantial reduction in time. Areas where the treatment is being applied to both the shallow- and intermediate-depth zones may result in an economy of scale because a single location could be used to inject chemical oxidant in both zones.

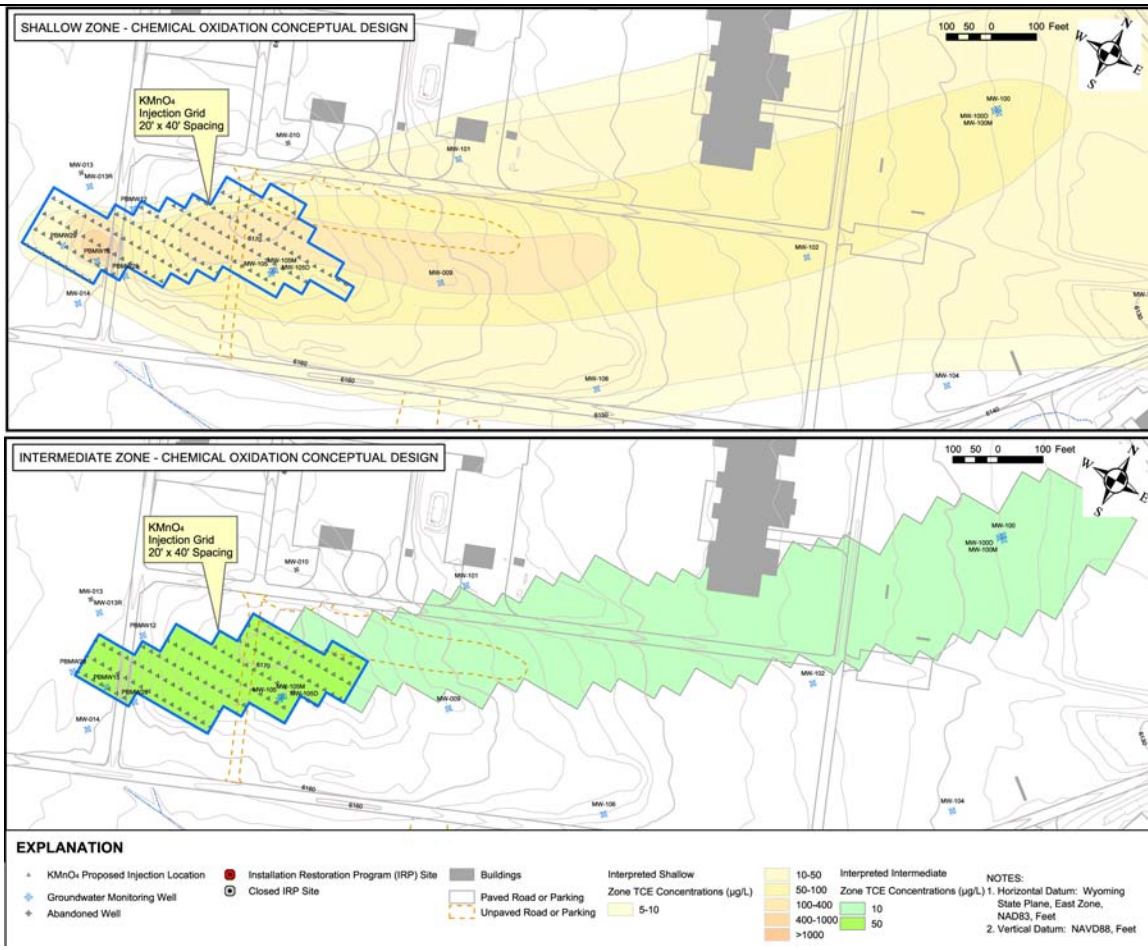


FIGURE 9 – CONCEPTUAL LAYOUT OF PREFERRED ALTERNATIVE FOR PLUME B

PLUME C

PLUME C NATURE AND EXTENT

In Plume C, TCE was the only organic compound that exceeded Wyoming Groundwater Standards and MCLs. The maximum reported concentration from Zone D Groundwater RI data was 2,273 µg/L (the Zone D Source Areas RI reported 6,870 µg/L from a temporary well and 6,400 µg/L from a permanent well). The downgradient edge of Plume C extends to Crow Creek, and trace TCE concentrations (3.67 µg/L) in MW-1018S, north of the creek, indicate a portion of the plume is migrating underneath the creek.

Current TCE concentrations have decreased relative to historic maximum concentrations in some wells and increased relative to historic maximum concentrations in other wells. Based on the Source Areas RI, an active source no longer exists above the water table. Some contaminants may still be dissolved into groundwater from soil materials below the water table where residual amounts are adsorbed onto soil particles. Smaller, local sources may also have historically contributed to Plume C contamination. Based on the contaminant distribution and trend analyses, there were suspected localized sources of TCE in the vicinity of FPTA2 and ADW. In February 2003, additional investigations were conducted to determine whether there were independent sources or whether the concentration trends were a function of localized plume dynamics. Based on investigation results, it was concluded that the concentrations and trends were representative of localized plume dynamics. Areas where increasing trends occur are addressed by active treatment alternatives. MNA is retained as a viable element of the alternatives for areas of the plume which are stable or shrinking.

PLUME C SUMMARY OF REMEDIAL ALTERNATIVES

Table 6 summarizes the remedial alternatives for Plume C, with the preferred alternatives in bold text. Surface water RAOs are also addressed by these alternatives.

Table 6 – PLUME C – REMEDIAL ALTERNATIVE SUMMARY

Alternative	Description	Timeframe to Achieve Surface Water RAOs (Years)	Timeframe to Achieve Groundwater RAOs (Years)	Capital Costs	Total O&M Costs	Average O&M Costs	Present Value Cost
1C	No Further Action	55[1]	70[1]	NA	NA	NA	$0
2C	LUCs[2]	55[1]	70[1]	$18,484	$167,090	$2,387	$63,775
3C	Groundwater Extraction, Treatment, and MNA	<5	30	$2,082,278	$11,069,595	$368,987	$8,168,509
4C	**Chemical Oxidation at Plume Head, Localized Chemical Oxidation, MNA, and PRB**	**<5**	**50**	**$3,439,306**	**$3,787,487**	**$75,750**	**$4,861,129**
5C	ERH, Localized Chemical Oxidation, MNA, and PRB	<5	50	$5,954,943	$3,939,330	$78,787	$7,280,204
6C	Groundwater Extraction, Treatment, Localized Chemical Oxidation, and MNA	<5	50	$3,460,848	$5,610,616	$112,212	$6,391,207
1C-INT	No Further Action	N/A	100	NA	NA	NA	$0
2C-INT	LUCs[2]	N/A	100	$0	$69,223	$692	$1,132
3C-INT	**MNA**	**N/A**	**100**	**$0**	**$3,200,364**	**$32,004**	**$659,702**
4C-INT	Localized Chemical Oxidation and MNA	N/A	60	$1,771,712	$1,522,530	$25,375	$2,307,002

RAO – Remedial Action Objective
LUC – Land Use Controls
O&M – Operation and Maintenance
MNA – Monitored Natural Attenuation
NA – Not applicable
INT – Intermediate

[1]Due to increasing TCE concentration trends observed in Plume C, the timeframe for natural attenuation (i.e., No Further Action and LUCs) cannot be simulated/modeled. To perform the modeling and generate the referenced timeframes, it was assumed that TCE concentrations are no longer increasing, but attenuating. The timeframes referenced for the active treatment alternatives (4C, 5C, and 6C) are viable because the treatment addresses those areas of the plume that exhibit increasing concentrations.

<5 - Remedial alternatives 3C, 4C, 5C, and 6C reflect essentially an "immediate" effect in achieving the surface water RAO. The "<5" years is a function of the time units used for the modeling calculations (see Volume 2 of the FS).

[2]LUCs are a component of all remedies with the exception of Alternative 1 (No Further Action).

All technologies pertaining to Plume C alternatives have been described in previous sections with the exception of Alternative 4C. For this reason, none of the technologies pertinent to the other remedial alternatives are described here.

Alternative 4C – Chemical Oxidation at Plume Head, Localized Chemical Oxidation, PRB, and MNA

For costing purposes, the plume head (TCE ranging from 2,273 to 6,870 µg/L) would be treated with Fenton's Reagent and the localized, lower concentration areas (TCE ranging from approximately 350 to 470 µg/L) would be treated using $KMnO_4$. The preferred oxidant would be determined during the design phase. A PRB would be installed at the leading edge of Plume C to reduce contaminant loading to the creek. As illustrated in Figure 10, the PRB is approximately 600 feet downgradient of the area being treated with chemical oxidation and therefore, there should be no incompatibility between these technologies. For cost estimating purposes, the PRB would be constructed using ZVI.

Field studies are currently underway at Plume C to evaluate a 125-foot test biomulch PRB. The biomulch PRB contains a mixture of locally derived, actively-composting, shredded plant material (bark mulch) and coarse sand. This treatment method relies on the flow of groundwater under a natural hydraulic gradient through the biowall to promote contact with soluble organic matter. Under these conditions, microbial fermentation of organic carbon with the biowall produces hydrogen which supports the reductive dechlorination of TCE in the groundwater. The objective of the field application is to assess the viability of the biowall in treating TCE and its degradation products in the shallow groundwater of Plume C. The performance of the biomulch PRB will be assessed to determine the final placement and configuration of the proposed PRB construction.

PLUME C EVALUATION OF ALTERNATIVES

In accordance with EPA guidance, the performance of each alternative is evaluated against the nine criteria listed in Table 3.

1. Overall Protection of Human Health and Environment

All of the Plume C alternatives except the "No Action" Alternatives would provide adequate protection of human health and the environment by eliminating, reducing, or controlling risk through treatment, engineering controls, and/or LUCs. Because the "No Action" Alternatives (1C and 1C-INT) are not protective of human health and the environment, they were eliminated from consideration under the remaining eight criteria.

2. Compliance with ARARs

Alternatives 3C, 4C, 5C, 6C, 3C-INT, and 4C-INT would meet their respective ARARs from Federal and State laws. Alternatives 3C and 6C also require compliance with the substantive requirements of an NPDES discharge permit. Alternatives 2C and 2C-INT would not comply with potential chemical-specific ARARs because there is no means of monitoring plume attenuation. Because Alternatives 2C and 2C-INT would not comply with ARARs, they were eliminated from consideration under the remaining seven criteria.

3. Long-term Effectiveness and Permanence

Shallow Zone: Alternatives 3C, 4C, 5C, and 6C include LUCs which would limit or prevent use of groundwater and continued monitoring would provide a reliable means to assess the treatment effectiveness.

Treatment in Alternative 3C would reduce the TCE concentration in groundwater to 50 µg/L in approximately 20 years. Natural processes will reduce the TCE concentration in groundwater to the MCL approximately 10 years after completion of treatment. Activated carbon would contain the TCE; however, it would be shipped off site for destruction through regeneration. Greater O&M is needed only during 10-year treatment period.

Alternative 4C includes chemical oxidation using Fenton's Reagent at the head of the plume and $KMnO_4$ in areas with groundwater TCE concentrations greater than 300 µg/L. These applications would reduce localized contaminant concentrations to the MCL in six months. Continued treatment by groundwater flow through a PRB at the toe of the plume and natural processes would reduce the remaining TCE concentrations in groundwater to MCLs in approximately 50 years. Greater O&M would be required only during the six-month in-place treatment period.

Alternative 5C uses in-place treatment using ERH at the head of the plume and $KMnO_4$ in areas with groundwater TCE concentrations greater than 300 µg/L. As with Alternative 4C, these actions would reduce contaminant concentrations to the MCLs in six months and continued treatment and natural processes would reduce the TCE concentration in groundwater to the MCL in approximately 50 years. As with Alternative 4C, greater O&M would be needed only during the six-month in-place treatment period.

Alternative 6C uses $KMnO_4$ injection in areas with groundwater TCE concentrations greater than 300 µg/L and would reduce the TCE groundwater concentration in the treated areas to the MCL in 6 months (as with Alternatives 4C and 5C). *Ex-situ* treatment at the head of the plume would reduce the local TCE groundwater concentrations to the MCL within approximately 5 years. Continued treatment by groundwater flow through a PRB at the toe of the plume and natural processes would reduce the remaining TCE concentrations in groundwater to the MCL approximately 45 years after completion of the *ex-situ* treatment. Greater O&M is needed only during the five-year *ex-situ* treatment period.

Intermediate-Depth Zone: Alternatives 3C-INT and 4C-INT include LUCs which would limit or prevent use of groundwater and continued monitoring would provide a reliable means to assess the treatment effectiveness.

Alternative 3C-INT has natural processes which will reduce contaminant levels in groundwater to MCLs over time. TCE groundwater concentrations would be reduced to the MCL in approximately 100 years. Continued monitoring and LUCs provide a reliable means to assess the residual concentrations and manage the risk posed by the residual. No residual contamination would be produced by the Alternative 3C-INT process and minimal O&M of wells and groundwater sampling are required.

Alternative 4C-INT employs active treatment followed by MNA to reduce TCE concentrations in the intermediate groundwater zone. This alternative will reduce TCE Concentrations to below the MCL is approximately 60 years. Continued monitoring provides a reliable means to assess the treatment effectiveness. Greater O&M is required only during the six-month treatment period.

4. Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Shallow Zone: TCE levels in groundwater are reduced to MCLs through irreversible processes under Alternatives 3C, 4C, 5C, and 6C. Alternatives 4C and 5C will reduce toxicity, mobility, and volume over time from treatment of groundwater and natural processes. Alternative 3C reduces the toxicity, mobility, and volume of TCE over time from treatment of groundwater and natural processes. TCE is adsorbed to activated carbon. Alternative 6C reduces TCE toxicity, mobility, and volume over time from treatment of groundwater.

Intermediate-Depth Zone: TCE levels in groundwater are reduced to MCLs through irreversible processes under Alternatives 3C-INT and 4C-INT. Alternative 3C-INT reduces the toxicity, mobility, and volume of TCE over time through natural attenuation of contaminants in groundwater. Alternative 4C-INT will reduce toxicity, mobility, and volume over time from active treatment of groundwater and natural processes. No residuals are expected to be present in groundwater at completion of Alternatives 3C-INT and 4C-INT.

5. Short-term Effectiveness

Shallow Zone: There would be minimal additional risk to site workers and the environment during construction for Alternatives 3C, 4C, 5C, and 6C. There would be no increased risk to workers, the community, or the environment during implementation of any of these four alternatives. For Alternatives 3C and 6C, transport of spent carbon vessel to offsite regeneration facility would pose minimal risk to the community.

Alternative 3C would be effective in achieving the RAOs in the shortest period (30 years). Alternatives 4C, 5C, and 6C would achieve MCLs in approximately 50 years.

Intermediate-Depth Zone: Alternative 3C-INT presents no additional risk to site workers and the environment because there is no construction of a treatment system. There would be no increased risk to workers, the community, or the environment during implementation of Alternative 3C-INT. Time to achieve MCLs within the plumes is approximately 100 years for Plume C.

There would be minimal additional risk to site workers and the environment during construction for Alternative 4C-INT. As in Alternative 3C-INT, there would be no increased risk to workers, the community, or the environment during implementation of Alternative 4C-INT. Alternative 4C-INT would be effective in achieving the RAOs in 60 years for Plume C.

6. Implementability

Shallow Zone: Alternatives 3C, 4C, 5C, and 6C are moderately easy to implement. Each employs technologies that are proven and reliable. Items and contractors required for each are readily available, except for ERH specialty contractors (Alternative 5C). Conventional drilling and well installation techniques would be used under each of these four alternatives and schedule delays are not likely. Monitoring the effectiveness is simple for each of these alternatives.

Administrative requirements for Alternatives 3C and 6C include compliance with the substantive requirements of an NPDES permit, preparation of an O&M Plan and LTM Plan, and modifying the General Plan. Alternatives 4C and 5C do not require an NPDES permit or an O&M Plan, but do require preparation of treatment system designs, LTM Plans, and modification of the General Plan.

Intermediate-Depth Zone: Alternatives 3C-INT and 4C-INT are easy to implement and schedule delays are not likely. Monitoring the effectiveness of each of these two alternatives is simple. Alternatives 3C-INT and 4C-INT rely on processes that do not require removal, aboveground treatment or TSD services. F. E. Warren administrative requirements include modifying the General Plan.

Alternative 4C-INT employs chemical oxidation which is a proven and reliable technology. The chemical oxidant ($KMnO_4$) is readily available. Conventional well drilling and installation techniques would be used. Multiple drilling contractors and

$KMnO_4$ suppliers are available and competitive bids can be obtained. Administrative requirements for Alternative 4C-INT include preparation of a treatment system design and LTM Plan, and modifying the General Plan.

7. Costs

Costs are presented in Table 6 Plume C – Remedial Alternative Summary.

8. State/Support Agency Acceptance

EPA and the WDEQ support the preferred alternative for Plume C: Alternative 4C/3C-INT (Chemical Oxidation at Plume Head, Localized Chemical Oxidation, MNA, and PRB for the shallow zone and MNA for the intermediate zone).

9. Community Acceptance

Community acceptance of the preferred alternative will be evaluated after the public comment period ends and will be discussed in the ROD for the site.

PLUME C SUMMARY OF THE PREFERRED ALTERNATIVE

The preferred alternative for cleaning up the Plume C groundwater is Alternative 4C/3C-INT. This alternative includes chemical oxidation for the chlorinated VOC contamination in the shallow zone at the head of Plume C and selected “hot spots”, a PRB to prevent contaminated groundwater from discharging to Crow Creek, and MNA for the remainder of the plume. For costing purposes, the plume head (TCE ranging from 2,273 to 6,870 µg/L) would be treated with Fenton’s Reagent and the localized, lower TCE concentration areas (approximately 350 to 470 µg/L) would be treated using $KMnO_4$. The preferred oxidant would be determined during the design phase. A conceptual layout of the proposed remedy is illustrated in Figure 9.

Groundwater sampling data and numerical modeling results suggest that the intermediate-depth zone plume is relatively stable and shrinking in size and contaminant mass (Volume 2 of the FS). The modeled time for TCE concentrations to be naturally attenuated to the MCL from present conditions in the intermediate-depth zone plume is approximately 100 years. LTM would allow for continued evaluation of contaminant migration and effectiveness of this alternative.

Chemical oxidation in the shallow zone addresses potential source areas and areas where concentrations have increased. It is the lowest cost of the active treatment alternatives with a moderate time frame. Small reductions in the time frame would require an unjustifiable increase in cost. In the intermediate zone, chemical oxidation is a little more than triple the cost of MNA but results in a substantial reduction in time over MNA. Chemical oxidation in both zones may allow for using the same injection zones over part of the plume and thus result in an economy of scale.

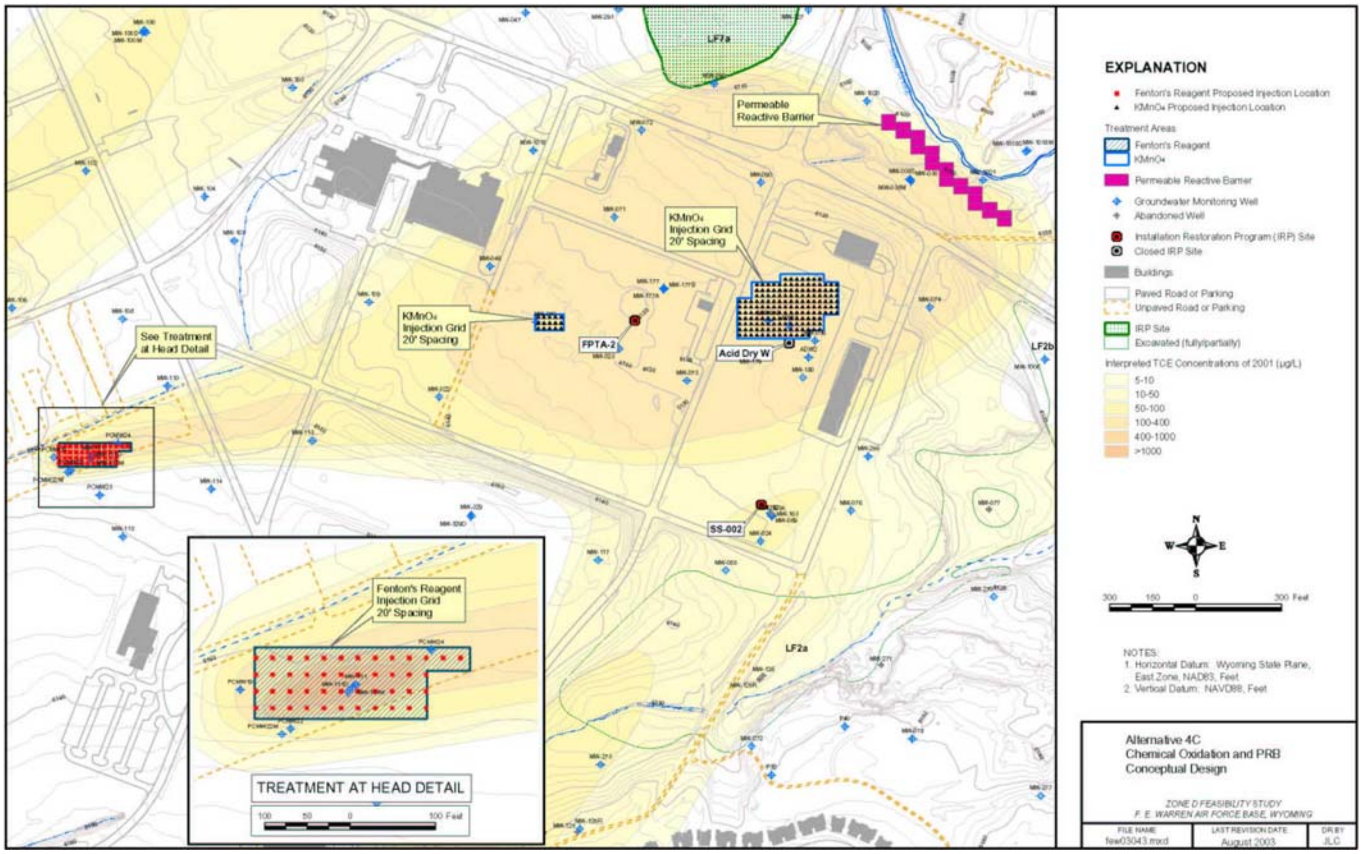


FIGURE 10 – CONCEPTUAL LAYOUT OF PREFERRED ALTERNATIVE FOR PLUME C

PLUME E

PLUME E NATURE AND EXTENT

In Plume E, MCL exceedances were reported for TCE, bis(2-ethylhexyl)phthalate, and benzene. Bis(2-ethylhexyl)phthalate was reported in one sample above its respective MCL, but is not considered to be site-related because of the distribution and recognition that it is a common field or laboratory contaminant. Benzene was reported only slightly above the MCL in one well. Additional investigation was conducted to delineate the extent and potential source of the benzene, but no other occurrences were identified.

The maximum TCE concentration reported in Plume E was 449.7 µg/L from MW-075S located at the approximate midpoint of the plume. This distribution suggests an attenuating plume originating from the vicinity of Building 945.

Plume E contributes to Crow Creek, a Class 2AB stream, which has a current regulatory limit of 2.7 µg/L. There has never been a documented exceedance of the WDEQ surface water quality standard and the loading calculations indicate that no exceedances are expected.

PLUME E SUMMARY OF REMEDIAL ALTERNATIVES

Table 7 summarizes the remedial alternatives for Plume E.

Table 7 – PLUME E – REMEDIAL ALTERNATIVE SUMMARY TABLE

Alternative	Description	Timeframe to Achieve Surface Water RAOs (Years)	Timeframe to Achieve Groundwater RAOs (Years)	Capital Costs	Total O&M Cost	Average O&M Costs	Present Value Cost
1E	No Further Action	0	70	NA	NA	NA	$0
2E	LUCs[1]	0	70	$18,484	$167,090	$2,387	$63,775
3E	**MNA and Existing PRB**	**0**	**70**	**$0**	**$4,711,571**	**$67,308**	**$1,627,952**
4E	Groundwater Extraction, *Ex-situ* Treatment, MNA, and Existing PRB	0	40	$1,351,304	$7,138,460	$178,462	$5,583,086
5E	Bioaugmentation, MNA, and Existing PRB	0	40	$9.022,858	$3,743,748	$93,593	$10,141,585
6E	Localized Chemical Oxidation, and MNA (without the Existing PRB)	0	40	$6,476,174	$3,497,868	$87,446	$7,714,007
1E-INT	No Further Action	NA	130	NA	NA	NA	$0
2E-INT	LUCs[1]	NA	130	$0	$140,833	$1,083	$1,298
3E-INT	MNA	NA	130	$0	$4,623,337	$35,564	$685,885
4E-INT[2]	**Localized Chemical Oxidation and MNA**	**NA**	**105**	**$566,322**	**$2,257,983**	**$21,504**	**$1,118,196**

RAO – Remedial Action Objective
LUC – Land Use Controls
O&M – Operation and Maintenance
MNA – Monitored Natural Attenuation
NA – Not applicable
INT – Intermediate

For Plume E, there has never been a documented exceedance of the WDEQ surface water quality standard and the loading calculations indicate that no exceedances are expected. Therefore, a zero (0) has been used for the surface RAO timeframe.

[1]LUCs are a component of all remedies with the exception of Alternative 1 (No Further Action).

[2]Hybrid of 4E-INT alternative to treat TCE concentrations in the intermediate zone in excess of 100 μg/L.

There is no surface water treatment option included for Plume E.

All remedial technologies presented for Plume E have been previously described in prior sections.

PLUME E EVALUATION OF ALTERNATIVES

In accordance with EPA guidance, the performance of each alternative is evaluated against the nine criteria listed in Table 3.

1. Overall Protection of Human Health and Environment

All of the Plume E alternatives except the "No Action" Alternatives would provide adequate protection of human health and the environment by eliminating, reducing, or controlling risk through treatment, engineering controls, and/or LUCs. Because the "No Action" Alternatives (1E and 1E-INT) are not protective of human health and the environment, they were eliminated from consideration under the remaining eight criteria.

2. Compliance with ARARs

Alternatives 3E, 4E, 5E, 6E, 3E-INT, and 4E-INT would meet their respective ARARs from Federal and State laws. Alternative 4E also requires compliance with the substantive requirements of an NPDES discharge permit. Alternatives 2E and 2E-INT would not comply with potential chemical-specific ARARs because there is no means of monitoring plume attenuation. Because Alternatives 2E and 2E-INT would not comply with ARARs, they were eliminated from consideration under the remaining seven criteria.

3. Long-term Effectiveness and Permanence

Shallow Zone: Alternatives 3E, 4E, 5E, and 6E include LUCs which would limit or prevent use of groundwater and continued monitoring would provide a reliable means of assessing the treatment effectiveness.

Alternative 3E includes the existing injected pilot PRB which would continue to treat groundwater in the vicinity of well MW-75, where the highest concentration of TCE has been observed. This localized treatment would continue for as long as 30 years. Natural processes will reduce contaminant levels to MCLs in the remainder of the groundwater plume in approximately 70 years. Continued monitoring and LUCs provide a reliable means to assess the residual concentrations and manage the risk posed by the residual. No untreated residual contamination would be produced by this process. Minimal O&M of wells and groundwater sampling are required.

Ex-situ and in-place treatments in Alternative 4E and 5E, respectively, would reduce the TCE concentration in groundwater to 50 µg/L in approximately 10 years. Natural processes will reduce the TCE concentration in groundwater to the MCL approximately 30 years after completion of treatments. Continued monitoring and LUCs provide a reliable means to assess the treatment effectiveness for these two alternatives. Greater O&M would be needed only during 10-year treatment period. Alternative 4E would require that the activated carbon containing the TCE at the end of the process be shipped off site for destruction through regeneration.

Alternative 6E employs active treatment that would reduce the TCE concentrations in groundwater to 50 µg/L in approximately six months. Natural processes will reduce the TCE concentration in groundwater to the MCL approximately 40 years after completion of active treatment. Continued monitoring provides a reliable means to assess the treatment effectiveness. Greater O&M is needed only during the six-month active treatment period.

Intermediate-Depth Zone: Alternatives 3E-INT and 4E-INT include LUCs which would limit or prevent use of groundwater and continued monitoring would provide a reliable means of assessing the treatment effectiveness.

Alternative 3E-INT has natural processes which will reduce contaminant levels in groundwater to MCLs over time. TCE groundwater concentrations would be reduced to the MCL in approximately 130 years. Continued monitoring and LUCs provide a reliable means to assess the residual concentrations and manage the risk posed by the residual. No residual contamination would be produced by the Alternative 3E-INT process and minimal O&M of wells and groundwater sampling are required.

Alternative 4E-INT employs active treatment to reduce the TCE concentrations in groundwater to 50 µg/L in approximately six months. Natural processes will reduce the TCE concentration in groundwater to the MCL after completion of active treatment. This will take approximately 35 years in Plume E. Continued monitoring provides a reliable means to assess the treatment effectiveness. Slightly greater O&M is required only during the six-month treatment period.

4. Reduction of Toxicity, Mobility, or Volume of Contaminants Through Treatment

Shallow Zone: TCE levels in groundwater are reduced to MCLs through irreversible processes under Alternatives 3E, 4E, 5E, and 6E. Alternative 3E reduces the toxicity, mobility, and volume of TCE over time from groundwater passing through the existing PRB and natural processes. No residuals are expected to be present in groundwater at completion of Alternative 3E. Alternative 4E will reduce toxicity, mobility, and volume over time from *ex-situ* treatment of groundwater and natural processes. TCE is adsorbed to activated carbon. Alternative 5E reduces the toxicity, mobility, and volume of TCE over time from in-place treatment of groundwater and natural processes. Alternative 6C reduces TCE toxicity, mobility, and volume over time from active treatment of groundwater and natural processes.

Intermediate-Depth Zone: TCE levels in groundwater are reduced to MCLs through irreversible processes under Alternatives 3E-INT and 4E-INT. Alternative 3E-INT reduces the toxicity, mobility, and volume of TCE over time from natural attenuation of contaminants in groundwater. Alternative 4E-INT will reduce toxicity, mobility, and volume over time from active treatment of groundwater and natural processes. No residuals are expected to be present in groundwater at completion of Alternatives 3E-INT and 4E-INT.

5. Short-term Effectiveness

Shallow Zone: Alternative 3E presents no additional risk to site workers and the environment because there is no construction of a treatment system. There would be minimal additional risk to site workers and the environment during construction for Alternatives

4E, 5E, and 6E. There would be no increased risk to workers, the community, or the environment during implementation of any of these four alternatives. For Alternative 4E, transport of the spent carbon vessel to offsite regeneration facility would pose minimal risk to the community.

Alternative 4E, 5E, and 6E are effective in achieving the RAOs in the shortest period of 40 years. Alternative 3E would achieve MCLs in approximately 70 years.

Intermediate-Depth Zone: Alternative 3E-INT presents no additional risk to site workers and the environment because there is no construction of a treatment system. There would be no increased risk to workers, the community, or the environment during implementation of Alternative 3E-INT. Time to achieve MCLs within the plumes is approximately 130 years for Plume E.

There would be minimal additional risk to site workers and the environment during construction for Alternative 4E-INT. As in Alternative 3E-INT, there would be no increased risk to workers, the community, or the environment during implementation of Alternative 4E-INT. Alternative 4E-INT would be effective in achieving the RAOs in 105 years for Plume E.

6. Implementability

Shallow Zone: Alternatives 3E and 6E are easy to implement and schedule delays are not likely. Monitoring the effectiveness of each of these two alternatives is easy. Alternative 3E makes use of the PRB and monitoring wells, which are already in place, and does not require removal, aboveground treatment or TSD services. Monitoring the effectiveness is simple. F. E. Warren administrative requirements include preparing a LTM Plan. Alternative 6E employs chemical oxidation, which is a proven and reliable technology. The chemical oxidant ($KMnO_4$) is readily available. Conventional well drilling and installation techniques would be used for Alternative 6E and multiple drilling contractors and $KMnO_4$ suppliers are available. Competitive bids can be obtained. Administrative requirements for Alternative 6E include preparation of a treatment system design and LTM Plan, and modifying the General Plan.

Alternatives 4E and 5E are moderately easy to implement and monitoring the effectiveness of each of these two alternatives is easy. Carbon adsorption is a proven and reliable technology. Carbon equipment (vessels, pumps) and regeneration services are readily available and competitive bids can be obtained.

Bioaugmentation has not been tested at F. E. Warren. Bioaugmentation (Alternative 5E) materials (microbes, stimulants) are also readily available. Conventional techniques would be used for both Alternatives 4E and 5E and schedule delays are not likely. For Alternative 5E, multiple drilling contractors are available and competitive bids can be obtained. Administrative requirements for Alternatives 4E and 5E include preparation of an O&M Plan and LTM Plan, and modifying the General Plan. Alternative 4E requires compliance with substantive requirements of an NPDES permit. Alternatives 4E and 5E require preparation of a treatment system design.

Intermediate-Depth Zone: Alternatives 3E-INT and 4E-INT are easy to implement and schedule delays are not likely. Monitoring the effectiveness of each of these two alternatives is simple. Alternatives 3E-INT and 4E-INT rely on processes that do not require removal, aboveground treatment, or TSD services. F. E. Warren administrative requirements include modifying the General Plan.

Alternative 4E-INT employs chemical oxidation which is a proven and reliable technology. The chemical oxidant ($KMnO_4$) is readily available. Conventional well drilling and installation techniques would be used. Multiple drilling contractors and $KMnO_4$ suppliers are available and competitive bids can be obtained. Administrative requirements for Alternative 4E-INT include preparation of a treatment system design and LTM Plan, and modifying the General Plan.

7. Costs

Costs are presented in Table 7 Plume E – Remedial Alternative Summary.

8. State/Support Agency Acceptance

EPA and the WDEQ support the preferred alternative for Plume E: Alternative 3E/4E-INT (Existing PRB, Localized Chemical Oxidation, and MNA).

9. Community Acceptance

Community acceptance of the preferred alternative will be evaluated after the public comment period ends and will be discussed in the ROD for the site.

PLUME E SUMMARY OF THE PREFERRED ALTERNATIVE

The preferred alternative for cleaning up the Plume E groundwater is Alternative 3E/4E-INT. This remedy consists of continued use of the PRB, localized chemical oxidation within the intermediate zone of Plume E, and MNA for the remainder of the plume. Groundwater modeling results have shown that the remedial time frame in the shallow zone of Plume E is 70 years. The preferred alternative for the intermediate zone is a hybrid of the original proposed alternative 4E-INT and will use chemical oxidation to treat TCE concentrations in excess of 100 μg/L. The groundwater model indicates a remedial time frame of approximately 105 years for the intermediate groundwater zone. The proposed LTM program is based on a 105-year monitoring period. A conceptual layout of the proposed remedy is illustrated in Figure 11.

Currently no exceedances of the surface water standard of 2.7 μg/L have been measured in Crow Creek. Mass loading calculations indicate that there will be no future exceedances.

MNA in the shallow zone is the lowest cost of the active alternatives with an estimated 70-year time frame. To get a reduction in time frame to about 40 years, costs would have to increase by 3-fold or more. The higher cost does not appear to be worth the partial reduction in time, particularly since the reduction would still result in decades of LTM. In addition, LTM would still be ongoing for the intermediate zone.

Alternative 4E-INT was not among the alternatives from the FS report, where the treatment options were not addressed because costs would have been an order of magnitude or more above the relative cost of MNA. However, intermediate zone alternatives are all relatively long-term. Alternative 4E-INT was developed for this proposed plan and is intended to achieve a more manageable time frame without orders of magnitude increase in cost. While the cost is about double that of MNA, it is still at a moderate level. The treatment would result in a reduction of about 25 years. While 105 years is still a long time frame, it is considered more manageable. While lower-level contaminant concentrations may remain for a long time, most of the higher concentrations would be treated in the immediate short term.

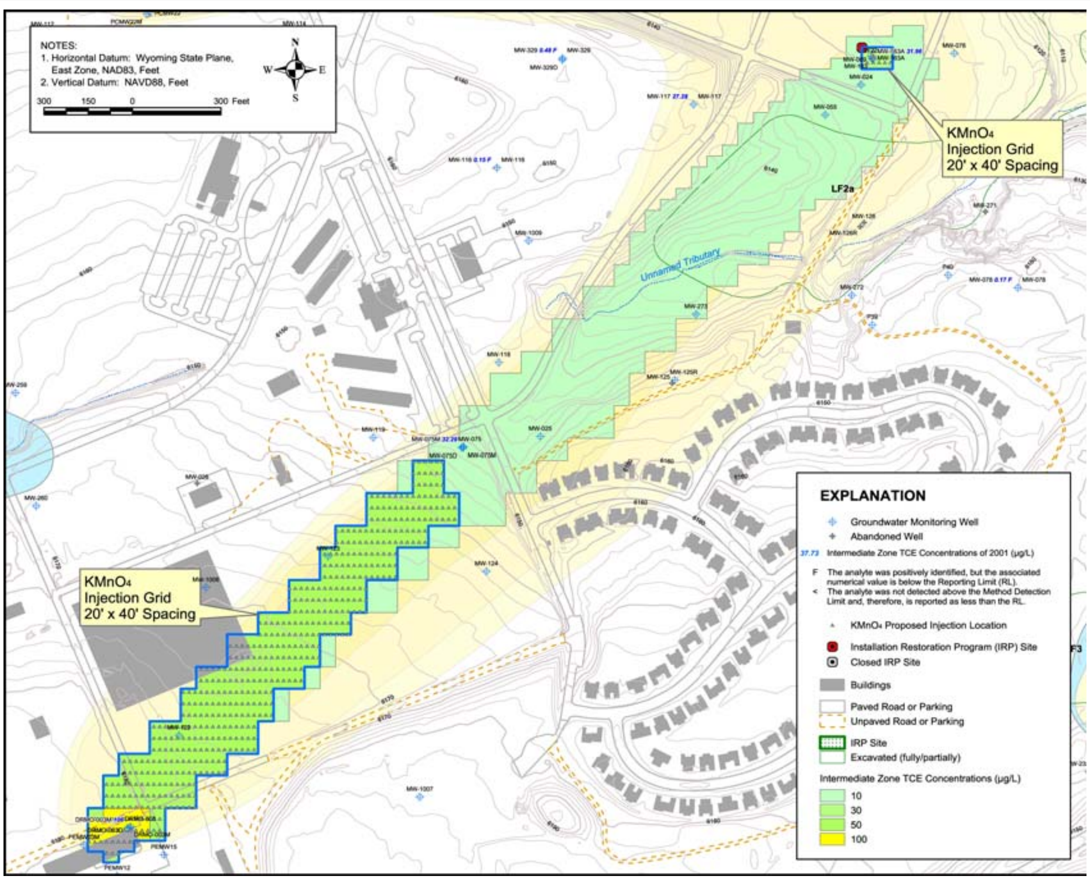


FIGURE 11 – CONCEPTUAL LAYOUT OF PREFERRED ALTERNATIVE FOR PLUME E

Table 8 – SUMMARY OF PREFERRED REMEDIES FOR ZONE D GROUNDWATER

Zone within Plume	Description of Preferred Alternatives
PLUME A	
Shallow	**3A-MNA:** Natural attenuation combining natural processes to achieve cleanup with a comprehensive monitoring program. Based on groundwater modeling results, TCE concentrations throughout the shallow zone will be naturally attenuated to 5 µg/L in approximately 50 years, with a cost of $2,616,440.
Intermediate	**3A-INT-MNA:** Natural attenuation combining natural processes to achieve cleanup with a comprehensive monitoring program. Based on groundwater modeling results, TCE concentrations throughout the intermediate zone will be attenuated to 5 µg/L in approximately 120 years, with a cost of $4,452,780. The total cost for Plume A to be naturally attenuated is estimated to be $7,069,220.
SPILL SITE 7	
Shallow	**5S-PRB, BIO, MNA:** The existing PRB will continue to protect the surface water interface of SS7. A combination of bioaugmentation and MNA will address the VOC contamination in groundwater for the upgradient SS7 plume. Based on groundwater modeling results, TCE concentrations throughout the shallow zone will be attenuated to 5 µg/L in approximately 35 years, with a cost of $2,284,053.
Intermediate	**4S-INT-CO, MNA:** This option uses chemical oxidation, followed by MNA to treat the low TCE concentration (<81.6 µg/L) groundwater in the intermediate zone of SS7. Based on groundwater modeling results, TCE concentrations throughout the intermediate zone will be attenuated to 5 µg/L in approximately 175 years, with a cost of $5,244,772. The total cost for SS7 to achieve MCLs is estimated to be $7,528,825.
Surface Water	**Option 1S-CDS:** Channel drop structures will be placed to promote aeration and volatilization of TCE at an estimated cost of $60,000.
PLUME B	
Shallow	**5B-CO, MNA:** This option uses chemical oxidation, followed by MNA to treat TCE in the shallow zone of Plume B. Based on groundwater modeling results, TCE concentrations throughout the shallow zone will be attenuated to 5 µg/L in approximately 35 years, with a cost of $3,247,947.
Intermediate	**4B-INT-CO, MNA:** This option uses chemical oxidation, followed by MNA to treat the intermediate zone of Plume B. Based on groundwater modeling results, TCE concentrations throughout the intermediate zone will be attenuated to 5 µg/L in approximately 35 years, with a cost of $1,279,268. The total cost for Plume B is estimated to be $4,527,215.
PLUME C	
Shallow	**4C-INT-CO, MNA:** This option uses chemical oxidation, followed by MNA to treat TCE in the shallow zone groundwater of Plume C. Based on groundwater modeling results, TCE concentrations throughout the shallow zone will be attenuated to 5 µg/L in approximately 50 years, with a cost of $3,787,487.
Intermediate	**3C-INT-MNA:** Natural attenuation combining natural processes to achieve remediation objectives with a comprehensive monitoring program. Based on groundwater modeling results, TCE concentrations throughout the intermediate zone will be naturally attenuated to 5 µg/L in approximately 100 years with a total cost of $3,200,364. The total cost for Plume C is estimated to be $6,987,851.
PLUME E	
Shallow	**3E-PRB, MNA:** The existing PRB followed by MNA will treat TCE in the shallow groundwater zone of Plume E. Based on groundwater modeling results, TCE concentrations throughout the shallow zone will be attenuated to 5 µg/L in approximately 70 years, with a cost of $4,711,571.
Intermediate	**4E-INT-CO, MNA:** This option uses chemical oxidation, followed by MNA to treat TCE in the intermediate groundwater zone of Plume E. Based on groundwater modeling results, TCE concentrations throughout the intermediate zone will be attenuated to 5 µg/L in approximately 105 years, with a cost of $2,257,983. The total cost for Plume E is estimated to be $6,969,554.
SS2 **SS4** **FPTA2** **LF2**	**No Further Action:** These are locations for which response actions to treat soils were previously implemented. There is no evidence that groundwater at these locations has been impacted by the individual spill sites or landfill; however, these sites lie within the footprint of the larger plumes (i.e., Plumes A, C, and E). Therefore, no further action is planned for SS2, SS4, FPTA2, and LF2. Groundwater contamination underlying these sites is attributed to the larger plumes and will be addressed by the planned response actions for the respective plumes.

Abbreviations:
BIO = Bioaugmentation; CDS = Channel Drop Structure; CO = Chemical Oxidation
ERH = Electrical Resistance Heating; FPTA = Fire Protection Training Area; LF = Land Fill
LUCs = Land Use Controls; MNA = Monitored Natural Attenuation; PRB = Permeable Reactive Barrier
SS = Spill Site; VOC = Volatile Organic Compound

Note: Preferred alternatives for each of the zones within each of the five plumes are highlighted in red text.

COMMUNITY PARTICIPATION

Based on the information available at this time, the USAF, EPA, and WDEQ believe the preferred alternatives will be protective of human health and the environment, will comply with ARARs, are reliable, will reduce contaminant mobility, and will provide the most cost-effective long-term solutions. Depending on new information, or public response, the preferred alternatives can change.

The USAF, EPA and WDEQ provide information regarding the cleanup of F. E. Warren to the public through public meetings, the Administrative Record for the site, periodic newsletters, direct mailing to interested parties, and announcements published in the *Wyoming Tribune-Eagle*. The USAF, EPA, and WDEQ encourage the public to gain a more comprehensive understanding of the site and the Superfund activities that have been conducted at the site. The dates for the public comment period; the date, location, and time of the public meeting; and the locations of the Administrative Record files are provided on the front page of this Proposed Plan.

For further information on Zone D Groundwater please contact:

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GLOSSARY OF TERMS

Specialized terms used in this Proposed Plan are defined below:

Administrative Record – a record of documents and correspondence for the Installation Restoration Program under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA).

Adsorption – A process in which a soluble contaminant is removed from groundwater by contact with a solid surface (i.e., soil).

Analyte – the sample constituent whose concentration is sought in a chemical analysis.

Applicable or relevant and appropriate requirements (ARARs) – the federal and state environmental laws that a selected remedy will meet. These requirements may vary among sites and alternatives.

Biodegradation – Transformation or destruction of contaminants induced by the metabolic activity of microorganisms.

Contaminant of Concern (COC) – A site contaminant which occurs at a concentration that poses an unacceptable threat to human health and the environment.

Contaminant of Potential Concern (COPC) – A contaminant selected for further evaluation in a human health or ecological risk assessment because it may threaten human health or the environment. COPCs are first identified as potential site contaminants – a chemical present at elevated concentrations attributable to site activities.

Dilution – A reduction in contaminant concentration, but not in the mass of the contaminant.

Dispersion – A reduction in contaminant concentration though spreading and mixing of the contaminant plume with uncontaminated groundwater.

Groundwater – underground water that fills pores in soils or openings in rocks to the point of saturation.

Long term monitoring (LTM) – Physical and chemical measurements over time (several years) to evaluate performance.

Monitored Natural Attenuation (MNA) – MNA makes use of natural processes to contain the spread of contamination from chemical spills and reduce the concentration and amount of pollutants at contaminated sites. Environmental contaminants are left in place while physical, biological, and chemical processes such as dilution, volatilization, biodegradation, dispersion, adsorption, and chemical reactions with subsurface materials are allowed to reduce contaminant concentrations to acceptable levels.

Monitoring – Ongoing collection of information about the environment that helps gauge the effectiveness of a cleanup action.

Operations and maintenance (O&M) – operating a treatment system and performing system maintenance and repairs.

Present value costs – By discounting costs that occur over different time periods to a common base year, the costs for different remedial action alternatives can be compared on the basis of a single figure for each alternative. When calculating present worth cost for Superfund sites, total operations and maintenance costs are to be included.

Remedial Action Objectives (RAO) – the stated objectives for actions at the site.

Sorbed-phase material – Contaminants accumulated on the surface of a solid (i.e., soil)

Volatile organic compounds (VOC) – Carbon compounds, such as solvents, oils, and pesticides. Some VOCs can cause cancer.

Volatilization – Transfer of a contaminant from a liquid phase to a gaseous phase.

ACRONYMS USED IN THIS PROPOSED PLAN

μg/L	micrograms per liter
ADW	Acid dry well
ARAR	Applicable and Appropriate Requirements
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cm^3/g	cubic centimeters per gram
COC	Contaminants of concern
COPCs	Contaminants of potential concern
DCE	Dichloroethene
DNAPL	Dense, non-aqueous phase liquid
EE/CA	Engineering Evaluation/Cost Analysis
EPA	Environmental Protection Agency
ERH	Electrical resistance heating
ERPIMS	Environmental Restoration Program Information Management System
F. E. Warren	F. E. Warren Air Force Base
FPTAs	Fire protection training areas
FS	Feasibility Study
GAC	Granular activated carbon
H_2O_2	Hydrogen peroxide
IRA	Interim remedial action
IRP	Installation Restoration Program
kg	kilograms
$KMnO_4$	Potassium permanganate
LFs	Landfills
LTM	Long-term monitoring

LUCs	Land Use Controls
MCL	Maximum contaminant level
MNA	Monitored natural attenuation
MnO_2	Manganese dioxide
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
O&M	Operations and maintenance
OUs	Operational Units
PRB	Permeable reactive barrier
RAO	Remedial Action Objective
RI	Remedial Investigation
ROD	Record of Decision
SPH	Six-phase heating
SS	Spill site
SVE	Soil vapor extraction
TCE	Trichloroethene
TSD	Treatment, storage and disposal
USAF	United States Air Force
VOC	Volatile organic compound
WDEQ	Wyoming Department of Environmental Quality
WSA	Weapons storage area
WWQRR	Wyoming Water Quality Rules and Regulations
ZVI	Zero-valent iron

USE THIS SPACE TO WRITE YOUR COMMENTS

Your input on the Proposed Plan for Zone D Groundwater is important to the USAF. Comments provided by the public are valuable in helping the USAF select a final cleanup remedy for the site.

You may use the space below to write your comments. Detach, fold, and mail this page. Comments must be postmarked by 24 March 2005. If you have any questions about the comment period, please contact John Wright at (307) 773-4147 or submit your comments to the USAF via email at the following e-mail address: john.wright@warren.af.mil. Verbal comments may also be submitted at the public meeting.

Name ______________________________

Address ______________________________

City ______________________________

State ____________________________ Zip __________

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